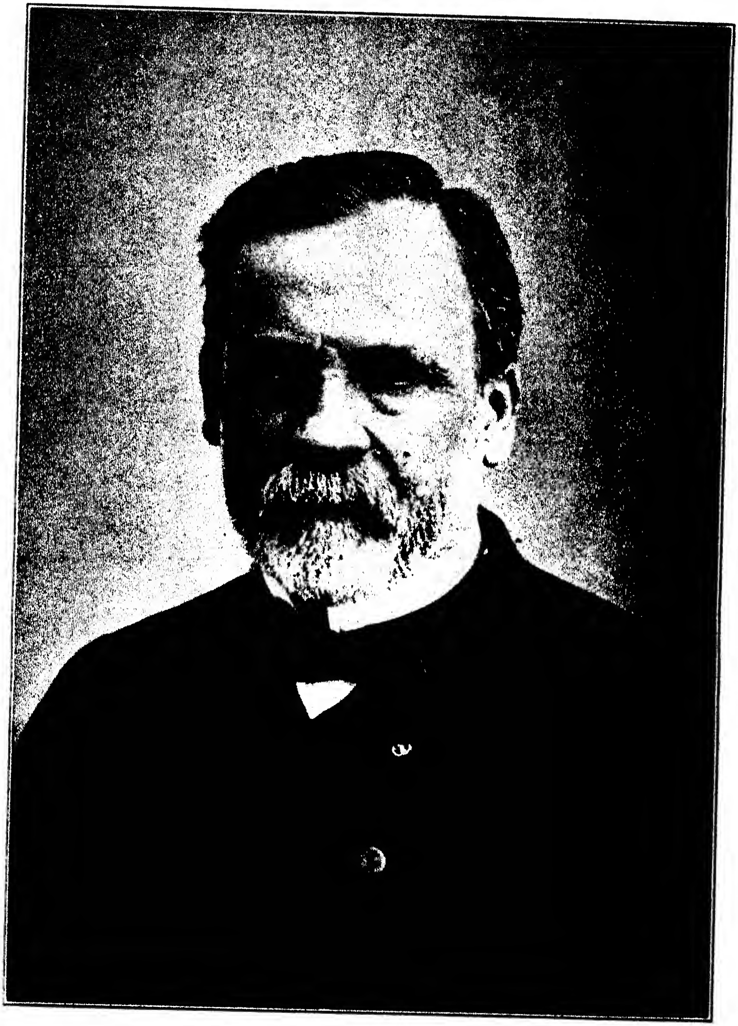
ELEMENTARY HUMAN BIOLOGY



LOUIS PASTEUR

CHEMIST AND BIOLOGIST

"He saved more lives than Napoleon took in all his wars."

See pages 168–170

ELEMENTARY HUMAN BIOLOGY

BY

JAMES EDWARD PEABODY, M.A.

HEAD OF THE DEPARTMENT OF BIOLOGY, MORRIS HIGH SCHOOL BRONX, NEW YORK CITY, AUTHOR OF "STUDIES IN PHYSIOLOGY" AND "LABORATORY EXERCISES IN ANATOMY AND PHYSIOLOGY

AND

ARTHUR ELLSWORTH HUNT, PH.B.

HEAD OF THE DEPARTMENT OF BIOLOGY, MANUAL TRAINING HIGH SCHOOL, BROOKLYN, NEW YORK CITY

New York
THE MACMILLAN COMPANY
1919

Set up and electrotyped. Published February 1913.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

TO

THE MEMORY OF

MARTHA FREEMAN GODDARD

WHOSE DEVOTED INSTRUCTION IN BIOLOGY IS A LASTING

INFLUENCE FOR GOOD IN THE LIVES OF HUNDREDS

OF BOYS AND GIRLS AND WHOSE RARE SKILL

IN LEADERSHIP IS AN INSPIRATION TO

EVERY TEACHER WHO KNEW HER

THIS BOOK IS DEDICATED

BY THE AUTHORS

PREFACE

The present volume is the third section of the authors' *Elementary Biology*. It has been issued in response to a demand for a brief text-book that can be used in a course in physiology and hygiene alone.

The authors believe that practical hygiene should be taught as effectively as possible, and that the necessity for good food, pure air, varied exercise, and sufficient sleep should be continually emphasized. If boys and girls can be led to conform their daily habits to the principles of healthy living, the course in human biology will have its highest justification.

In the treatment of Stimulants and Narcotics, the authors have tried to state in simple language the conclusions of experts regarding the effect of tobacco and alcohol, and to present the strongest scientific arguments against the use of these substances which are so injurious to growing youths. This text meets all the requirements relative to temperance instruction in the various states.

In our judgment there are few, if any, biological topics that are more important in their practical bearing than is that of bacteria. As commonly studied, the disease-producing effects of these organisms are emphasized so much that boys and girls do not appreciate that all the work of the higher organisms depends ultimately upon the activity of these low forms of plant life. In order to bring out this aspect of the work of bacteria, we have called special atten-

tion to the structure, physiology, and economic benefit of these organisms. But since so much may be done to prevent disease, we have also considered with some degree of thoroughness the disease-producing effects of several of the pathogenic forms.

No study of human biology should be allowed to leave in the mind of the student the idea that he is merely a chemical engine adapted only for the generation of a certain amount of physical energy. The primary object of all secondary education should be the development of character and efficiency, and the true teacher ought to find opportunity again and again to touch the individual life of the young student. Especially should this be true in the study of biology. Growing boys and girls ought to come to feel, as they have never felt, that they have in their keeping a most complex and wonderful piece of living machinery which can be easily put out of order or even wrecked. But, on the other hand, they should see that if the bodily machine is well cared for, it is capable of splendid work which may help to increase the sum total of human efficiency and happiness.

Much of the manuscript of the chapter on Foods received the careful criticism of the late Professor W. O. Atwater. Dr. William H. Park, Director of the Laboratories of the New York Board of Health, and Dr. Thomas Spees Carrington, Secretary of the National Association for the Study and Prevention of Tuberculosis, have given invaluable assistance in the preparation of the chapter on microörganisms. A considerable part of the "Human Biology" was critically read by Dr. F. C. Waite of the Western Reserve Medical School, by Mr. Harold E. Foster of the English Department of the Morris High School, and by the late Miss Martha F. Goddard of the Morris High School, to

whose memory this volume is dedicated. We wish, also, to express our hearty appreciation of the generous permission of Henry Holt & Co. to use some of the material published in Peabody's "Laboratory Exercises in Anatomy and Physiology."

Cost prices for the items on the list of laboratory apparatus and equipment were kindly furnished us by Bausch & Lomb, Kny-Scheerer, and O. T. Louis; from these prices the estimates on pp. 173 to 177 were prepared.

J. E. P.
A. E. H.

October 31, 1914.

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HUMAN BIOLOGY

CHAPTER I

THE GENERAL STRUCTURE OF THE HUMAN BODY

1. Regions of the body. — In man and in most other mammals one can distinguish at least three regions; namely, the head, neck, and trunk. To the trunk are attached two pairs of appendages; namely, two arms and two legs, or, as they are more often called in the descriptions of the lower animals, the four legs. If the front wall of the trunk (composed largely of skin and muscle) were removed, it would be found that this region of the human body is divided into an upper story or *chest cavity* (Fig. 1), and a lower story or *abdominal cavity*. These two cavities are separated from each other by a flexible partition called the *diaphragm*, which is composed largely of muscle more or less in the form of a dome. The chest and abdominal cavities, separated by a diaphragm, are characteristic of all mammals.

2. Organs of the body.[1] — When we study the body more closely, especially its interior, we find, in various regions, parts that carry on special kinds of work (Fig. 2). Within the chest cavity is the *heart*, which forces blood through the

[1] Each of the structures named in this paragraph should be demonstrated on a manikin or a chart before the textbook lesson is assigned. While studying the lesson, the pupil should find in Fig. 2 each of the organs named.

body. Here, also, are the *lungs,* which take in oxygen and give it to the blood, and which remove carbon dioxid, water, and other waste matters from the blood. Below the diaphragm are the *stomach* and the *intestines,* the *liver* and the

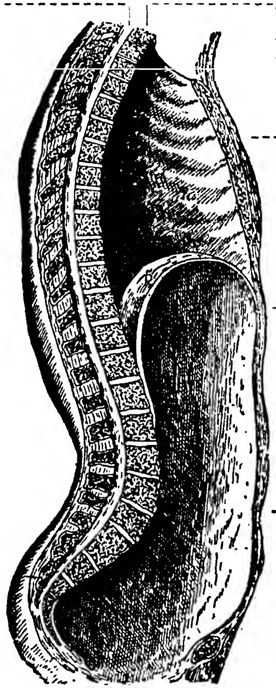


FIG. 1.—Longitudinal section of trunk (side view).

pancreas, all of which help to change our food into liquid form ready to be used by the body. All these and other parts of the body are called *organs. An organ is a part of a living body that has some special work to do; this special work is called its function.* Our hands, for example, are organs

because with them we do some special work like writing, sewing, or playing the piano.

3. Tissues of the body. — When we squeeze the arm or the hand, we feel the hard *bones* within that form the skele-

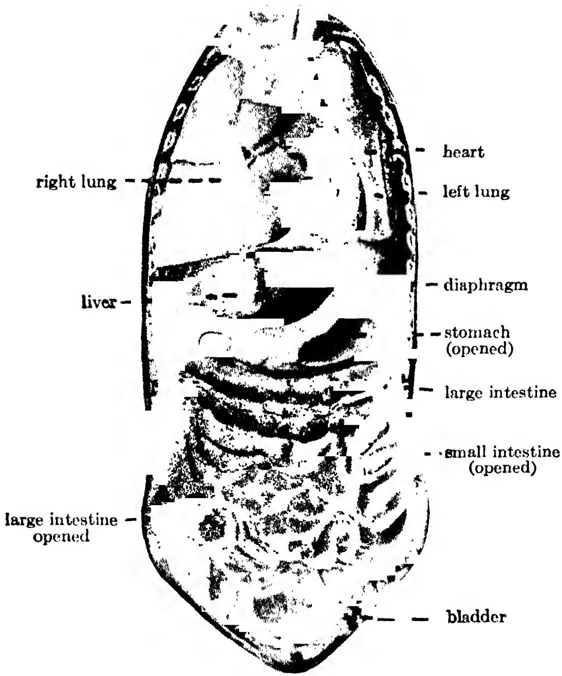


Fig. 2. — Organs of chest and abdomen (front view).

ton. We can raise from the bones the softer fleshy material, which is composed of muscle covered by skin. By clenching the fingers tightly we can see and feel on the inner side of the wrist the tough cords or *tendons* of *connective tissue* that

attach the muscles to the bones. If we run a clean needle point into the finger, blood flows; in this way we discover another of the materials found in our hand; namely, *blood.* This experiment also demonstrates that the human body has some structures by the help of which sensations of touch or pain are perceived. All the parts of the hand we have been enumerating are known as *tissues.* For the present *a tissue may be defined as one of the building materials of which an organ is composed.* In the hand we have found evidence of the presence of bone tissue, muscle tissue, connective tissue, blood tissue, and nerve tissue. Other kinds of tissue will be discussed in the pages that follow.

In order to go farther in our study of structure we need the aid of the compound microscope. With this instrument we discover that the tissues are by no means the simplest part of an animal.

4. Cells lining the mouth. — Laboratory study.

Materials: Cells from the human body may be readily prepared by gently scraping with the finger nail the mucous membrane lining the mouth and then rubbing the material thus obtained on a clean glass slide, adding a drop of water and a cover glass. The cells may be stained with iodine in order to show the nucleus more sharply. If time allows, prepared sections of the brain, intestines, skin, and other organs of the body may well be shown.

Examine with the low power of the compound microscope the cells prepared as described above.

1. Describe the form and color of each cell before it is stained with iodine.
2. In the cells stained with iodine notice a body, usually near the center, that is more deeply stained than the rest of the cell. This is the *cell nucleus,* and the rest of the cell is known as the *cell body.* The nucleus may be seen in the unstained cells as a denser portion.

a. Name, now, two parts of a cell from the membrane lining the mouth.

b. State the form and position of the cell nucleus.

3. Make a drawing of two of the cells described above (each cell to be represented about an inch in diameter). Label cell body and cell nucleus.

4. (Optional.) Demonstrate by the use of prepared slides, pictures, or charts that the brain, the intestine, and other organs of the body are composed of cells (Fig. 3).

5. **Cells and protoplasm.**[1] — Under the microscope cells at first appear to be only plane surfaces surrounded by lines (Fig. 3). In reality, however, each cell has not only length and breadth, but also thickness. Cells in animals and human beings differ from those in plants in never having cell walls of *cellulose*, and often cell walls are entirely wanting. If present, the cell wall is so transparent that it is possible to look through it and see the cell body and nucleus within.

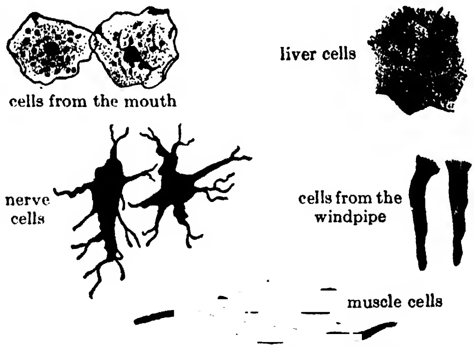


FIG. 3. — Cells from tissues of body.

The discovery of these minute bodies of which organs are composed was not made until about the middle of the last century (1838). With the rather imperfect microscopes then in use the two discoverers, Schleiden and Schwann, could see the walls only, and they did not know, as we now

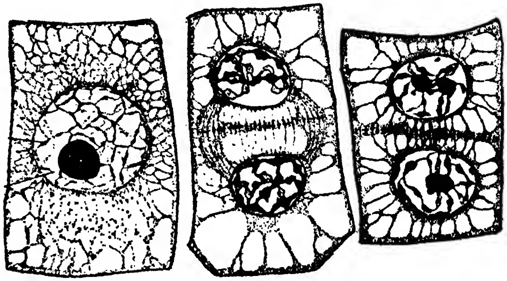
[1] Because of the importance of emphasizing cellular structure, the substance of §§ 42 and 43, "Plant Biology," are here inserted.

know, that the most important part of the cell is not the lifeless wall of cellulose, but the living substance which is found inside the cell wall, making up a large part of the cell body and cell nucleus. To this substance is given the name *protoplasm*. We know now that the living substance or protoplasm is the essential part, while the wall may be missing, so that in such a case there is no resemblance to a cell or box. Biologists now understand *a cell to be a bit of protoplasm (cell body) containing a nucleus* (which is a denser portion of the protoplasm).

Protoplasm, when examined with the highest powers of the microscope, appears as a colorless, semifluid substance, in which are often seen solid particles or granules, which are probably little masses of food. The nucleus, as already stated, is commonly found near the center of the cell, and is composed of protoplasm denser than the protoplasm of the rest of the body of the cell. The appearance and composition of the protoplasm surrounding the nucleus, that is, the cell body, may be well represented by raw white of egg; but in making this comparison one should bear in mind that the white of an egg is not living substance.

6. Assimilation, growth, and cell division. — Within the protoplasm are foods in solution (such as sugar, protein, and mineral matters). These are used by cells in their growth and repair, and in the various kinds of work that they carry on. In the human body, as in plants, the food materials are gradually changed by protoplasm into living substance like itself. To this process is given the name *assimilation* (Latin, *ad* = to + *similis* = like). As a result of the process of assimilation the amount of protoplasm of course increases and the cell grows. Were this process to continue indefinitely, cells would come to be large in size. This, however,

does not occur; for when a cell reaches its normal size, the nucleus divides (Fig. 4), and the halves separate from each other to form two nuclei. The cell body now divides into two parts, and cell walls are formed between the two cells. Thus are produced two cells, each having its own nucleus, and these in turn assimilate and divide. In this way the number of cells increases with the growth of the body.



A, cell before division. *B*, cell with divided nucleus. *C*, single cell divided into two cells.

FIG. 4. — Cell division.

7. Cells of the blood. — If we were to examine with the compound microscope a drop of fresh blood,[1] we should find that it is not the simple red liquid it seems to be; it consists of solid particles, called *blood corpuscles,* floating in a watery liquid known as *blood plasma.* These corpuscles are single cells. Two kinds can be distinguished, which from their color are known as *red corpuscles* and *white corpuscles* (Fig. 5).

There are three hundred to seven hundred times as many red corpuscles as white. We shall first consider the white corpuscles. Each consists of a minute bit of protoplasm in which is imbedded a nucleus. These cells of the blood

[1] The blood may be easily obtained by tying a cord tightly about the finger and then pricking it with a needle cleaned by an antiseptic like peroxid of hydrogen or by heating it in a flame. A drop of blood is squeezed out upon a glass slide and covered with a thin cover glass.

have a characteristic method of locomotion, in the process of which they change their shape; they can creep along in a direction opposite to that of the blood current, and they

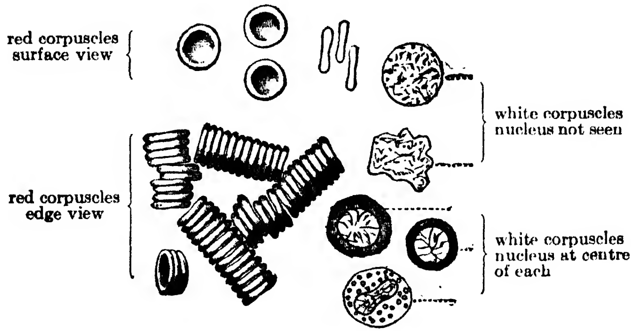


Fig. 5.—Cells of human blood.

have even been seen forcing their way through the walls of small blood vessels by pushing out slender processes called false feet. They then wander about in the tissues of the body, and, as we shall soon see, do us great service. The white corpuscles closely resemble in structure and functions a kind of single-celled animal called the Amœba (A. B.,[1] Fig. 120).

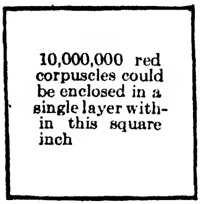


Fig. 6.—Number of red corpuscles in a square inch.

The *red corpuscles* have no power of independent motion. They are circular disks, concave on both surfaces. Some idea of the minute size of these cells may be gained from the fact that ten millions of them would just about cover a space one inch square. There is no nucleus in the red corpuscles; they are, however, formed from cells having a nucleus.

[1] A. B. = "Animal Biology."

8. Cells in other tissues. — It has been demonstrated that nerve tissue, muscle tissue, and other building materials of the body are all composed of cells (Fig. 3). *A tissue may now be defined as a building material of the body, composed of cells of the same kind.*

CHAPTER II

MICROÖRGANISMS AND THEIR RELATION TO HUMAN WELFARE

I. Structure and Functions of Bacteria

9. Bacteria:[1] **their microscopical appearance and size.** — In the preceding chapter we considered to some extent the organs, tissues, and cells of the human body. However, before we discuss further the structure and functions of these various parts of our bodies, we shall study in some detail certain microscopic plants which have a most intimate relation to human welfare. Chief among these are the tiny organisms known as *bacteria*.

Every one is familiar with the fact that if a bouquet of flowers is left for some time in a vase of water, the stems decay and disagreeable odors are given off. This is a common example of the action of bacteria, for all decay is due to the work of these organisms. When we come to examine the flower stems or the putrid water, we find a slimy scum. If we put a drop of this scum on a slide, cover with a cover glass, and examine with the highest powers of the microscope, we usually see many different forms of living things. Some of them appear relatively large, and these, as we have already seen (**A. B.**, Chapter VI), are single-celled animals. A closer examination will disclose countless numbers of very minute,

[1] The substance of this section, and several of those that follow, appear in Part I, "Plant Biology." Many teachers, however, find it impracticable to discuss bacteria until the work in human biology is taken up; hence the repetition of this material in this volume.

colorless organisms; these are the bacteria. A careful study of many kinds of bacteria shows that they have several characteristic shapes (see Fig. 7), by means of which they may be roughly classified. Some are rod-shaped (like a firecracker), some are spherical, or egg-shaped, and still others are spiral-shaped. *Each bacterium is a tiny bit of translucent protoplasm, inclosed in a cell wall of cellulose.* Thus far no nucleus has been discovered in any kind of bacteria. Because of their cellulose walls, and because of their likeness to certain low forms of green plants, biologists now regard these organisms as plants rather than animals.

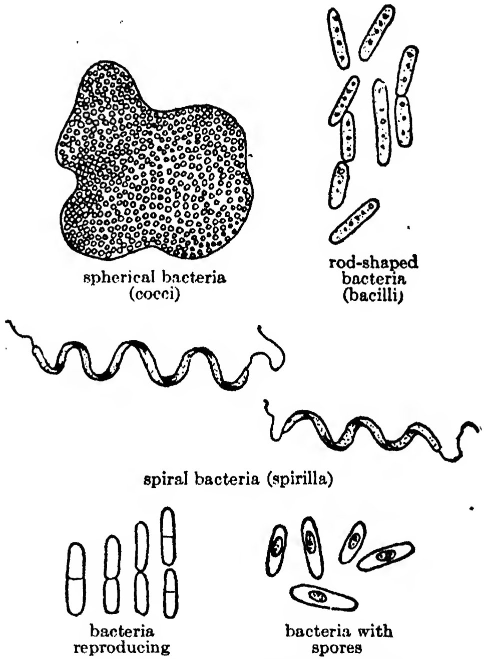


FIG. 7. — Various forms of bacteria.

Some kinds of bacteria have one or more long, hairlike projections from the ends, called *cil'i-a,* which give the germs still further resemblance to firecrackers. These cilia lash about rapidly, and thus drive the cell through the water. The spiral bacteria roll over and over, and advance in a spiral path like a corkscrew.

It is very difficult to get any clear notion of the extreme minuteness of bacteria. It means little to say that the rod-shaped forms are $\frac{1}{5000}$ of an inch in length. The imagination may be somewhat assisted if we remember that fifteen hundred of them arranged in a procession end to end would scarcely equal the diameter of a pin head.

10. Microscopic study of bacteria. — Laboratory demonstration.

Place on a glass slide a drop of the scum found on the surface of a hay infusion, and cover with a cover glass. Examine with the highest powers of the compound microscope.

1. Describe the source of the material you are examining.
2. What is the apparent color of the tiny bodies (bacteria) that you see?
3. Which of the different forms of bacteria shown in Fig. 7 do you find? Draw enlarged figures of each of the shapes that you find.
4. Do any of the bacteria seem to be in motion? If so, describe the motion.

11. Reproduction of bacteria. — When conditions are favorable, the production of new cells goes on with marvelous rapidity. The process is something as follows: the tiny cells take in through the cell wall some of the food materials that are about them, change this food into protoplasm, and thus increase somewhat in size. The limit is soon reached, however, and the bacterium begins to divide crosswise into halves. The mother cell thus forms two daughter cells by making a cross partition (cell wall of cellulose) between the two parts (Fig. 7). If the daughter cells cling together, a chain or a mass is formed. Oftentimes they separate entirely from each other. In either case the whole mass of bacteria is called a *colony*.

It usually takes about an hour for the division to take

place. Suppose, then, we start at ten o'clock some morning with a single healthy bacterium. If conditions are favorable, there would be two cells at eleven o'clock, and by twelve o'clock each of these two daughter cells would form two granddaughter cells; the colony would then number four individuals. Should this process continue for twenty-four hours or until ten o'clock on the day after the single bacterium began its race, the colony would number 16,777,216 bacteria. "It has been calculated by an eminent biologist," says Dr. Prudden,[1] "that if the proper conditions could be maintained, a rodlike bacterium, which would measure about a thousandth of an inch in length, multiplying in this way, would in less than five days make a mass which would completely fill as much space as is occupied by all the oceans on the earth's surface, supposing them to have an average depth of one mile."

12. Spore formation in bacteria. — Such startling possibilities as those suggested in the preceding section fortunately can never become realities, for favorable conditions soon cease to exist and the cells either die or cease to multiply. Sometimes, when food or moisture begins to fail, the protoplasm within each cell rolls itself into a ball and covers itself with a much thickened wall. This protects it until it again meets with conditions favorable for growth. The process we have been describing is known as *spore formation;* the tiny *protoplasmic* sphere is called a *spore,* and its dense covering a *spore wall* (Fig. 7). In this condition bacteria may be blown hither and yon as a part of the dust. They may be heated even above the temperature of boiling water without being killed. When at length they settle down on

[1] "The Story of the Bacteria," by Dr. T. Mitchell Prudden. G. P. Putnam's Sons, New York.

a moist surface that will supply them with food, the spores burst their thick envelope, assume once more their rod-shaped or spiral form, and go on feeding, assimilating, and reproducing their kind.

II. Occurrence of Bacteria

13. Are bacteria present in the air. — Laboratory demonstration.

Materials: The best method of cultivating bacteria is by the use of a nutrient agar mixture in Petri dishes, which is prepared as follows: —

To prepare 1000 cc. (about a quart) of agar mixture, weigh out 10 grams of salt, 10 grams of peptone, 10 grams Liebig's beef extract, and 10 grams of agar. Measure into an agate stewpan 1000 cc. of water, and stir in the salt, peptone, beef extract, and agar (the latter having been cut into small pieces). Heat the mixture in a double boiler until the agar is wholly melted. Slowly stir in just enough baking soda to cause red litmus paper to turn blue; *i.e.* the mixture should be *slightly* alkaline. When the pieces of solid agar have all disappeared, the hot liquid should be filtered into flasks of 250 cc. capacity through several rather thick layers of absorbent cotton placed in a funnel. This filtration might well be done by placing the flasks in a steam sterilizer. If the filtrate is not clear, the liquid should be poured through the same layers of cotton till it does become clear. Care should be taken to keep the agar mixture hot during the filtering process, otherwise the agar will not pass through the cotton. When the flasks are nearly full, plug the mouth of each with a large wad of cotton batting, put them into a steam sterilizer, and heat them at least thirty minutes on each of three successive days to make sure that all germs and their spores are killed. The flasks of agar may then be kept as a stock mixture until needed.

Carefully clean and dry enough Petri dishes to supply, if possible, seventeen or more dishes for experiments with each division

of students. Put the closed dishes in an oven and heat to a high temperature (150° C.) for an hour to kill any germs or spores that may be on the dishes. Allow the oven to cool before opening the door; otherwise the dishes are likely to crack.

To fill the Petri dishes, melt the agar mixture in a steam sterilizer, then arrange the sterilized Petri dishes along the edge of a horizontal surface. Carefully remove the cotton plug from the flask, lift one edge of the cover of one of the Petri dishes, pour enough of the hot agar mixture into the lower part of the dish to make a layer about an eighth of an inch deep, and quickly replace the cover on the dish. Quickly pour into each of the dishes in turn. After the agar has hardened, the dishes are ready for the experiments. Any agar mixture left in the flasks should be sterilized for thirty minutes on each of three successive days in order to make sure that it will keep for subsequent use.

Treat several of the Petri dishes of agar as follows: Label the first dish No. 1 and keep it closed throughout the experiments. Place a second Petri dish on the desk of a pupil, remove the cover and thus for ten minutes expose the surface of the agar to the air of a classroom or laboratory; label it dish No. 2. In a similar manner expose the surface of dish No. 3 for ten minutes to the air near the floor of a corridor through which classes are passing. Put all three dishes aside for a few days in a dark place where the temperature is 80° to 90° (*e.g.* in a furnace room), and then examine each dish.

1. State the difference in the treatment of dishes No. 1, No. 2, and No. 3. In what respects have all three been treated alike?
2. The spots on the surface of the agar are *colonies of bacteria*, each one of which has developed from a single bacterium (see Fig. 11). Which of the three dishes has the largest number of bacteria colonies?
3. Suggest a reason for the difference in the number of bacteria colonies in the three dishes.
4. What do you infer, therefore, as to the presence of bacteria in the air?

5. (Optional.) Make careful drawings at intervals of several days to show the difference in the number of colonies in the dishes, and the change in the size and appearance of the colonies.

14. Are bacteria present in water, milk, and other foods? — Laboratory demonstration.

Allow the water to run from the faucet for several minutes, and then spread a drop on the surface of dish No. 4. Spread a drop of milk on the surface of the agar in dish No. 5. On the agar surface of dish No. 6 put a bit of raw meat, a bit of apple peel, and bits of other kinds of food. Put the dishes in a warm, dark place as directed above, and examine at the end of several days.

1. State the difference in the treatment of dishes No. 4, No. 5, and No. 6.
2. In which of the three dishes do you find bacteria colonies? Describe the colonies in each dish as to position, number, and color.
3. What do you infer as to the presence of bacteria in water, milk, and other foods that you have tested?

15. Are bacteria present on various parts of the human body? — Laboratory demonstration.

Touch the surface of the agar in dish No. 7 with the finger tips; lay a hair on another part of the surface, and touch a third part with a toothpick that has been used to scrape the teeth. Put the dish in a warm, dark place as above, and examine at the end of several days.

Describe fully this experiment, stating your observations and conclusions.

16. Distribution of bacteria. — From our study of the culture dishes we have learned that bacteria are very common organisms. In fact, they are doubtless the most abundant of all living things; for they are found not only in air, water, and milk; not only in countless numbers wherever dead plant or animal material is allowed to accumulate; but also, unfortunately, in living tissues.

17. To determine conditions favorable and unfavorable for the growth of bacteria. — Laboratory demonstration.

A. *The effect of different degrees of temperature.* — Expose for ten minutes three Petri dishes of nutrient agar to the air in a room or corridor when classes are moving about. Cover the dishes and label them No. 8, No. 9, and No. 10, respectively. Put dish No. 8 in a temperature of 80° to 100° F., and dish No. 9 in the refrigerator, or in some other equally cold place. Dish No. 10 should be put in a steam sterilizer and heated for thirty minutes on each of three successive days; it should then be kept in a warm, dark place.

1. Describe the difference in the treatment of dishes 8, 9, and 10.
2. At the end of a week examine each of the three dishes. What difference do you find in the relative number of colonies in them?
3. What do you conclude, therefore, as to the influence of each of these three different degrees of temperature on the growth of bacteria?

B. *Pasteurization of milk.* — (Optional.) If possible secure a Pasteurizer[1] (Fig. 8). Carefully clean with soap and hot water, inside and out, four of the glass bottles, fill each with milk that is fresh, and fasten on the stoppers.

[1] *Home Pasteurizers,— System Nathan Straus,* —each supplied with bottles and stoppers, may be bought at the Nathan Straus Pasteurized Milk Laboratory, 348 East 32d St., New York City, or at any of the Laboratory depots situated throughout the city. The manufacturer's price for the entire outfit is $1.50. The authors are indebted to the Nathan Straus Laboratories for the cut of the Pasteurizer, and for the directions quoted above. The circular also contains the following statements. "The advantage of Pasteurization over other systems, such as sterilization or boiling, consists in the lower degree of heat applied, which is sufficient to kill all noxious germs, while the nourishing quality and good taste of the milk are retained. . . . Before use, warm the milk — in the bottles — to blood heat. Never pour it into another vessel. The milk must not be used for children later than twenty-four hours after Pasteurization. Never use remnants."

Keep one bottle at the temperature of the laboratory, labeling it bottle No. 1, and put another, bottle No. 2, in the refrigerator. Pasteurize the other two bottles in accordance with the following directions: —

"Set the bottles into the tray. . . . The pot is then placed on a wooden surface (table or floor) and filled to the three supports (in the pot) with boiling water. Place the tray

FIG. 8. — Straus Pasteurizer.

with the filled bottles into the pot, so that the bottom of the tray rests on the three supports, and put cover on quickly. After the bottles have been warmed up by the steam for five minutes, remove the cover quickly, turn the tray so that it drops into the water. The cover is to be put on again immediately. This manipulation is to be made very quickly, so that as little steam as possible can escape. Thus it remains for twenty-five

minutes. Now take the tray out of the water, cool the bottles with cold water and ice as quickly as possible, and keep them at this low temperature till used."

Place one bottle of Pasteurized milk (No. 3) beside the bottle in the room temperature, and the other (No. 4) in the refrigerator beside bottle No. 2.

1. At the end of three days shake the two bottles kept at the room temperature and open them. Smell or taste of the milk in each. State your observations and conclusions.
2. In a similar manner, test the two bottles that have been kept on ice for a week. State your observations and conclusions.
3. Why are milk, meat, and other foods of the kind put into the refrigerator, especially in summer time? Does this kill the bacteria? How do you know?
4. Why are meats cooked, milk Pasteurized, and fruits boiled before they can be kept for any length of time?

C. *The effect of lack of moisture.*—Expose for ten minutes two Petri dishes of nutrient agar in a dusty room or corridor (as in *A* above). Place the two dishes (No. 11 and No. 12 side by side in a warm room (over 90°). Cover dish No. 11 and leave dish No. 12 uncovered.

1. Describe the similarity and the difference in the treatment of dishes 11 and 12.
2. How is the agar mixture affected by removing the cover?
3. In which dish do colonies of bacteria develop?
4. What do you conclude, therefore, as to the necessity of moisture for the growth of bacteria?
5. Why is hay dried before it is put into the barn? Name some foods used by man that are kept for a long time after being dried.
6. As a conclusion from these experiments (in *A*, *B* and *C*) state what conditions you have found favorable for the growth of bacteria

7. State also what conditions you have found that hinder the growth of bacteria.

D. The effect of antiseptics. — Prepare a *pure culture* of bacteria in dish No. 13 in the following manner. Heat a dissecting needle on a piece of platinum wire in a hot flame to kill all the germs upon it. When it cools, touch a colony of bacteria in a Petri dish with the needle-point or wire; carefully raise the cover of dish No. 13 and make several scratches in the agar (the date of the experiment or the number of the room may be scratched in this way). In a similar way prepare dish No. 14 and then pour over the surface some peroxid of hydrogen or other antiseptic solution. When the dishes have been treated as described above, put them in a warm, dark place for several days.

1. Describe the preparation of dishes 13 and 14.
2. In which of the two dishes do you find no colonies of bacteria at the end of several days?
3. Peroxid of hydrogen is employed in treating wounds. What reason have you for thinking bacteria would be killed by this treatment?

III. Bacteria as the Friends of Man

18. Relation of bacteria to soil fertility. — Having discussed somewhat the structure and functions of bacteria, we are now to consider the great importance of these microscopic organisms to human welfare. In the first place, were it not for their never ending activity, all life upon the earth would soon cease to exist. Let us see why this is so. When animals or plants die, their bodies fall upon the ground, and had not these lifeless masses been taken care of, the whole surface of the earth would long since have been covered with a vast number of unburied organisms. All this dead material, however, as we have seen, is food for the countless

bacteria; they cause it to decay, and thus decompose it into simpler chemical compounds that soak into the earth and may then be used in the nutrition of the higher plants. And since plants are constantly taking from the soil the food materials that they need, this soil would tend to become less and less fertile were it not for the work of the bacteria that cause decomposition. This is the reason why rotting manure adds to the fertility of soil.

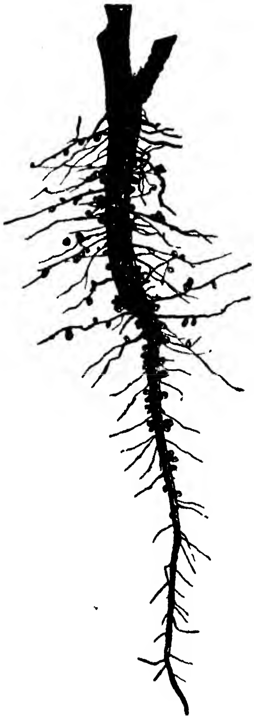


FIG. 9. — Roots of horse bean, with tubercles.

Again, it has been proved that certain kinds of bacteria directly increase the amount of nitrogen compounds that are so essential for plant growth. It has long been known that corn and other crops will grow better in soil that has just borne a crop of peas, beans, clover, or other members of the pea family. Within recent years an explanation of this fact has been found. When the roots of these pod bearing plants are examined, small swellings are seen (Fig. 9). These contain multitudes of bacteria that are able to take the free nitrogen from the air, where it exists in such abundance, and store it away in the form of nitrates, which are very important mineral matters needed by all crops. Since these bacteria can be put into soils that do not have them, it may be possible in the near future to restore much of the fertility that has been lost (Fig. 10).

19. Relation of bacteria to the flavors of food. — Again, many of the flavors of food are due to the action of bacteria. The flesh of animals, for instance, that have just been killed, is often tough and tasteless. If allowed to stand, however, these meats become tender and acquire their distinctive flavors by the decomposing action of bacteria. A similar action takes place when butter or cheese ripens, and the dairy industry has been perfected to such a degree that bacteria of certain kinds have been proved to give rise to definite flavors, and these bacteria may be produced in pure cultures for the dairymen.

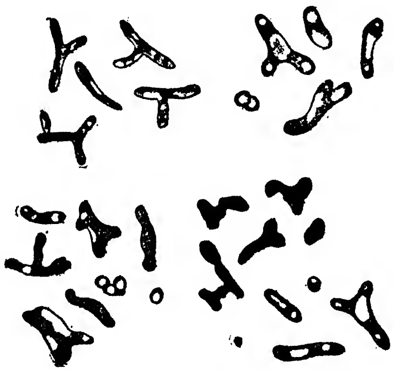


Fig. 10. — Bacteria from root tubercles.

20. Bacteria in the industries. — Without the help of bacteria the preparation of linen, jute, and hemp would be impossible. All these valuable products are plant fibers which are connected with woody materials so closely that they cannot be separated without first subjecting the stems of flax, hemp, and jute to a process of decay in large tanks of water. Moisture and warmth induce the rapid growth of germs, and the resulting decay loosens the tough fibers so that they may be separated from the useless parts of the plant. The change of alcohol into vinegar is also caused by bacteria. Formerly in the preparation of indigo other forms of bacteria were all-important, but at the present time indigo is largely made artificially.

IV. Bacteria as the Foes of Man

21. Injurious effects of bacteria. — Most of the common bacteria are either harmless or distinctly beneficial to mankind (**18–20**). The experiments we tried with milk (**17**, *B*), however, show that this kind of food soon sours unless it is kept in a very cold place. Every housekeeper knows also that meat and many other kinds of food quickly spoil if they are not cooked or otherwise preserved. In a following section we shall consider some of the methods that are used to prevent this decaying action of bacteria.

Unfortunately, too, there are certain germs [1] that find favorable conditions for growth in living animal tissue, and by their growth cause certain diseases, some of which are tuberculosis, diphtheria, and typhoid fever. In later sections we shall learn that these disease-producing bacteria are all too common in dust, water, and foods; but we shall likewise see that scientists are fast learning effective methods of *preventing* the ravages of these disease-producing bacteria, which are called by Dr. Prudden "Man's Invisible Foes." [2]

22. Methods of food preservation. — We saw in (**17**, *A* and *C*) that bacteria thrive whenever they can get plenty of food and moisture, and whenever the temperature is favorable for their growth. We also learned that, whenever any one of these necessary conditions is wanting, bacteria cease to carry on their functions. If, then, we wish to

[1] Disease-producing bacteria are commonly spoken of as *germs* or *microbes*.

[2] In general it is unwise and unnecessary that boys and girls should be taught much regarding the symptoms and effects of disease; but since so much may be done to *prevent* these diseases that we have mentioned and others that afflict mankind, it is essential that the young should learn something of the deadly work of some of the germs which are all too common.

keep food from spoiling, we need only to bring about conditions that are unfavorable for the growth of microörganisms.

For instance, everybody knows that meat, milk, and eggs must be put on ice in summer if they are to be kept for any length of time. Indeed, many food materials of this sort will remain in a more or less fresh condition for months or even years if they are in cold storage. It has been proved, however, that food products kept in cold storage for a long time are often unsafe for human consumption. On the other hand, we demonstrated (**17**, *A*) that a high degree of heat will kill bacteria, and so meats that have been cooked and milk that has been Pasteurized or scalded will keep longer than they do when left uncooked. If meats, vegetables, or fruits are heated to the boiling point in cans and sealed up at once, they may be permanently prevented from spoiling.

Ham and herring are often smoked to preserve them, while pork and codfish are soaked in a strong solution of salt (brine) to keep them from the decaying action of bacteria. Another method of preserving food is by depriving it of water. Dried beef, apples, hay, and seeds will keep indefinitely if no moisture is allowed to get to them. Previous to the passage of the Pure Food Law by Congress in 1906, many unscrupulous dealers were accustomed to use borax, formaldehyde,[1] and other chemicals to prevent their food supplies from spoiling. Fortunately for the health of the consumer, this method of food preservation has been largely stopped by the enforcement of the law to which we have just referred.

[1] *Method of determining whether or not formalin has been added to milk.* Into each of two test tubes or flasks put an equal quantity of fresh milk. To one of the glasses add a drop or two of formaldehyde solution. Then to each add a volume of hydrochloric acid equal to

23. To determine the best method of cleaning a room. — (Optional Demonstration.)

Select three rooms with rugs or carpets as nearly as possible of the same size and amount of dirt. Open Petri dish No. 15 and expose its surface for five minutes at the level of the table while one of the three rooms is being swept with a broom. In a similar manner expose the surface of dish No. 16 for five minutes to the air in a room that is being cleaned with a carpet sweeper, and dish No. 17 in the third room for five minutes while it is being cleaned with a vacuum cleaner. Close each of the dishes, label, and put in a warm place (90° to 100° F.) for several days.

1. Describe the preparation of dishes 15, 16, and 17.
2. What difference do you find in the relative number of bacteria colonies in the three dishes?
3. What do you conclude, therefore, as to the most effective method of removing dust and germs from a room?

24. Proper methods of sweeping and dusting. — From our experiments (**13, 23**) we have learned that large numbers of bacteria are present in the air of rooms where dust is raised by the movement of people or by sweeping. Since each colony started from a single bacterium, it is easy to show the relative number of germs present in the air under varying conditions (Fig. 11).

The number of bacteria that may be found in a church, schoolroom, theater, or living room has been proved by a

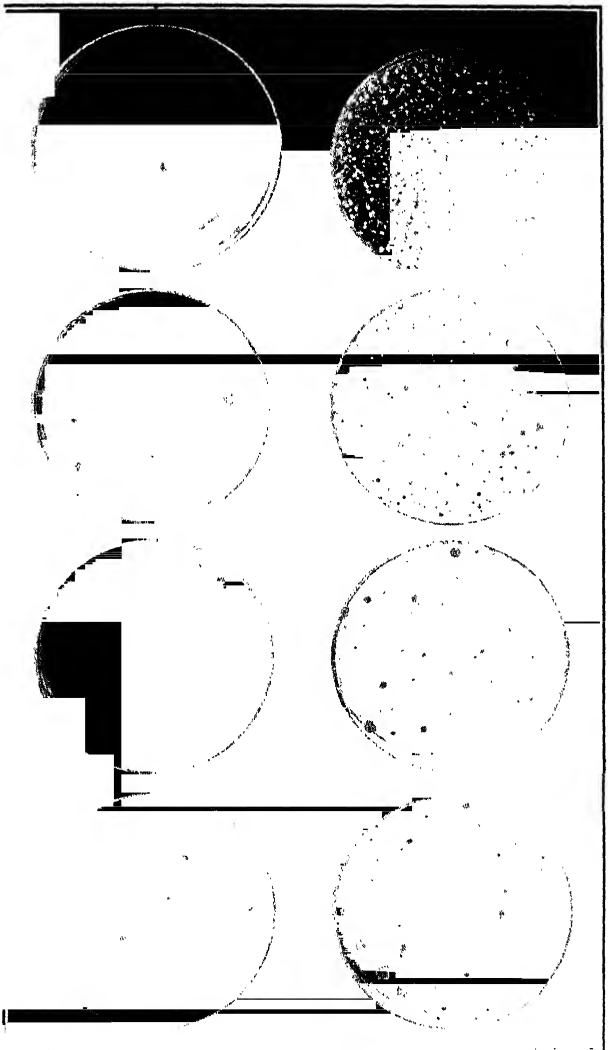
that of the milk and a drop of ferric chloride (made by dissolving a spoonful of ferric chloride in a quart of water). Put both dishes of milk into a dish of boiling water and stir or shake frequently for five minutes.

1. Describe the preparation of the experiment.
2. At the end of five minutes state the color produced in the milk in each of the two test tubes.
3. How, then, can you determine whether or not formalin has been added to milk?

long series of experiments to be enormous, for with the ordinary methods of "cleaning" these rooms, very few of the germs are removed. When a room is swept, most of the light dust particles are raised from the floor and mingled with the air. After a short time the room is "dusted," often with a feather duster. The bacteria which may have settled are whisked off again into the air. Experiments have shown, too, that the number of germs in a room is not materially diminished by ventilating currents, unless there is a strong draught.

Most of this germ dust can, however, be removed from our homes if they are cleaned in a proper manner. In a room that has not been used for three or four hours practically all of the bacteria and fine dust particles have settled out of the air upon the horizontal surfaces. For dusting, a cloth should always be used. "Dustless dusters" may be bought or prepared by soaking a piece of cheesecloth or flannel in a mixture of wax and turpentine, or by slightly sprinkling cheesecloth with water. By the use of these cloths most of the particles of dirt may be taken up and then removed from the cloths by washing. If carpets, rugs, and draperies are then cleaned with a vacuum cleaner, practically no dust is raised (Fig. 11); hence, further dusting is unnecessary. Careful investigation has demonstrated that the use of a vacuum cleaner on surfaces that may be washed or wiped with a cloth is too expensive a method of cleaning, and that it is not nearly as effective.

It is much more hygienic to have floors covered with rugs, for if a vacuum cleaner is not available, the dusty rugs and draperies may be removed from the room and cleaned in the open air. In general, a carpet sweeper is to be preferred to a broom as a means of cleaning carpets, since, as Fig. 11 shows, fewer germs are stirred up when the former is used.



A. Vacuum cleaner experiment. *B.* Carpet sweeper experiment. *C.* Wet paper and broom experiment. *D.* Dry broom experiment.

FIG. 11. — Upper row of dishes show bacteria colonies before sweeping; lower row, after sweeping. See footnote on p. 28. (Photographed by Mr. E. R. Sanborn, N. Y. Zoölogical Park.)

If brooms are used, small pieces of crumpled newspapers or tea leaves should be moistened and scattered on the floor before the sweeping is done.[1]

In cleaning public buildings, the floors should first be sprinkled with moist sawdust and then the coarser dirt collected by brushing with hair brooms. The floors should then be washed each day if possible.[2] Dirty streets, too, are a constant source of dust infection. Most of the irritation and possible diseases from this source would be avoided,

[1] Figure 11 shows, so far as bacteria are concerned, the comparative results obtained by four methods of sweeping. Four rugs of the same size and approximately the same amount of use were selected, and placed at night in four different rooms. Early the next morning a Petri dish was uncovered in each room, and thus the nutrient agar of each dish was exposed to the air of the room for five minutes; after which the dishes were covered.

A second set of four dishes was then opened in turn for five minutes while the four rugs were being cleaned as follows. Rug D was swept with a dry broom; rug C was covered with pieces of wet newspaper and then swept with a broom; rug B was cleaned with a carpet sweeper; and rug A was cleaned with a vacuum cleaner.

All of the eight dishes were then closed and kept in a warm room for five days and at the end of that time were photographed. (See Fig. 11.) The number of bacteria colonies in each dish were counted, and the results are expressed in the following table:

	No. Colonies before Sweeping	No. Colonies after Sweeping	No. Times Colonies were increased by Sweeping
Dish D	4	1190	297+
Dish C	6	436	72+
Dish B	7	135	19+
Dish A	25	118	4+

Hence over four times as many bacteria were stirred up by a carpet sweeper as by a vacuum cleaner, eighteen times as many when the sweeping was done with a broom and wet paper, and *over seventy times as many when a dry broom was used.*

[2] We are indebted to Mr. John H. Federer, Superintendent of the New York Public Library building, for valuable information contained in the preceding paragraphs.

however, if the citizens insisted that the streets be kept watered, especially when they are swept. Street sweeping and the removal of garbage should be done as far as possible at night.

25. Treatment of cuts. — A vast amount of discomfort and possible danger from bacterial infection in the body would be avoided if people but used proper care in the treatment of wounds. We have seen that white corpuscles resemble amœbæ in their structure and activities (**7**). Let us now study their functions in the human body. When one gets a sliver of wood in one's finger and leaves it there for a time, the finger becomes more or less swollen and sore, and white "matter" or *pus* usually forms in the region of the wound. These effects are principally due to the activity of bacteria, which were carried into the wound on the piece of wood. Finding in the tissues all the favorable conditions for growth, these minute organisms multiply rapidly and produce poisons called *toxins*, that cause the inflammation.

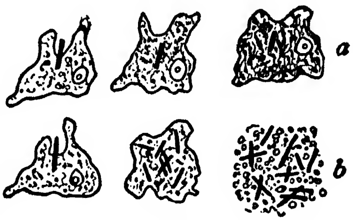


FIG. 12. — White corpuscles.

a = a white corpuscle devouring a bacterium.
b = a white corpuscle destroyed by bacteria.

As soon however, as these inflammatory processes begin, large numbers of white corpuscles are hurried to the spot and proceed to attack the invading bacteria. If the number of germs is relatively small, and if the corpuscles are in a healthy condition, these cells of the blood seize upon and devour the bacteria (Fig. 12) in the same way that an amœba takes in its food. Under these conditions little if any

pus is formed. But if the bacteria get the upper hand in the struggle, many of the corpuscles are killed, and it is the dead white corpuscles that form the pus.

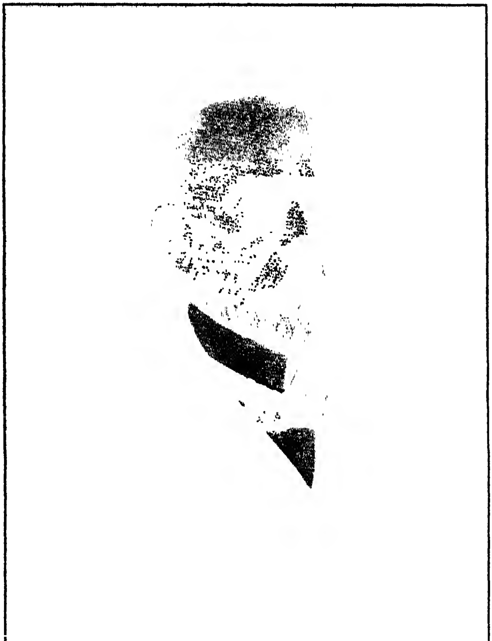


FIG. 13.—Dr. Robert Koch, German bacteriologist. Born 1843. Died 1910.

(From International Encyclopedia. Courtesy of Dodd, Mead & Co.).

In case of a cut the wound should be cleansed as quickly as possible with peroxid of hydrogen or some other germ-destroying solution, and should then be covered with absorbent cotton soaked in the peroxid solution and bandaged, to prevent the entrance of other germs. If this is not done, bacteria are likely to settle in the wound, and healing may be delayed or even more serious results may follow. With proper treatment a wound should show no signs of inflammation, or formation of pus, and should heal rapidly.

26. The cause of tuberculosis. — It is said that one seventh of all the deaths in the world are due to the disease

tuberculosis, which is more commonly known as *consumption.* In New York City alone the Board of Health reports 300 to 400 new cases every week. Yet if the general public only knew the manner in which this disease is transmitted and would make use of this knowledge, the dreadful sacrifice of life and health due to this " great white plague " could be almost wholly prevented.

It was conclusively proved in 1882 by Dr. Koch, a noted German scientist (Fig. 13),that tuberculosis is always caused by extremely small, rod-shaped bacteria, *bacillus tuberculosis* (Fig. 14). He found countless numbers of these living germs in the sputum coughed up by consumptive patients; he cultivated these germs in test tubes and when he injected the bacteria into the bodies of guinea pigs or rabbits, the animals became ill with tuberculosis. By many experiments of this sort, biologists have learned important facts in regard to the cause, prevention, and cure of disease.

FIG. 14.—Tuberculosis bacteria in human sputum. (Courtesy of Dr. Thomas S. Carrington.)

We are absolutely sure then, that before any one can become a consumptive, he must take into his body the living bacteria of consumption, and the most common avenue of infection is through the nose and air passages. Consumptives who are ignorant of the danger they are causing, frequently expectorate on the floors of rooms or of public conveyances, and when this sputum becomes dried, the germs are likely to be blown about in the air, and to be inhaled by

other people. When the bacteria get into the lungs of a person who happens to be a little "run down," as we say, straightway the bacteria begin to multiply, feeding meanwhile on the lung tissues; for this reason the disease is called consumption, and if it is not arrested, the lungs may be almost destroyed, and death, of course, results. During the progress of the disease, little masses or *tubercles* of lung tissue (whence the name *tuberculosis*) are thrown off by the patient in coughing, and these, as we have already stated, are swarming with living bacteria.

27. The prevention of tuberculosis. — It is of the utmost importance, therefore, that these living germs be kept out of the bodies of people who come in contact with consumptives. Responsibility in this matter rests very largely upon the patients themselves, and if they exercise the necessary care, they need not become a menace to healthy people in the home or in the community. It is of course essential that every effort be made to stop altogether the dirty and dangerous habit of spitting. Many people have the disease long before they are aware of it, and a general public sentiment should be developed that will actively assist boards of health in enforcing their rules against the "spitting nuisance." Every consumptive should provide himself with paper cups or cloths that may be burned, together with their contents.

Tuberculous patients should exercise care not to cough or sneeze without covering the mouth or nose with a handkerchief, for it has been proved that living germs are widely distributed by carelessness in this regard. Separate knives, forks, spoons, and drinking vessels, which ought to be cleaned in boiling water, should be set apart for consumptives. Kissing the lips of consumptives should never be permitted.

28. The cure of tuberculosis. — In former years the decision by doctors that a patient had tuberculosis was be-

lieved to be a sentence to a lingering death; it was believed also that the disease was hereditary. Happily modern medicine has dispelled both these beliefs. A child may inherit weak lungs or a frail body; but it will never be a

A. Tent open. *B*. Tent closed.

Fig. 15. — Window tent. (Courtesy of Dr. Thomas S. Carrington.)

consumptive unless the bacteria that cause this disease are in some way planted in his tissues. Consumption, too, is a curable disease, unless it is neglected until it has reached an advanced stage. The prime requisites in the treatment of the disease are a plentiful supply of fresh air, plenty of easily

digested and nutritious food, like eggs and milk, sleep and freedom from hard muscular work and from worry. These conditions may be obtained even in crowded cities, for by the use of tents on the roof, or of window tents (Fig. 15) a sufficient amount of air may be secured, and almost marvelous cures are found to result.[1]

29. The cause and treatment of pneumonia. — Another disease that affects the lungs is *pneumonia.* It is more prevalent in the spring and autumn of the year, and is commonly a disease of adults. The cause of pneumonia is a spherical form of bacteria, which get into the lung tissue and grow there when the individual is physically weak or mentally depressed. Formerly, in treating the disease, patients were kept in closed rooms, carefully shielded from all draughts of air. It has been found, however, as is the case with tuberculosis, that fresh outdoor air is one of the best means of treating the patient. To combat both tuberculosis and pneumonia, our bodies and minds should be kept in such a healthy and vigorous condition that invading disease germs will always meet with a hostile reception whenever they attempt to prey upon our organs and tissues.

30. Cause of diphtheria. — Another disease that formerly claimed many victims among young children is *diphtheria.* The germs of this disease are rod-shaped organisms somewhat larger than those that cause tuberculosis. When these bacteria find lodgment and grow in the throat, they produce a membrane and form poisonous substances known as *toxins,* which are absorbed and carried by the blood to other parts of the body, often causing paralysis and other injurious effects.

[1] The authors are much indebted to Dr. Thomas Spees Carrington for suggestions relating to tuberculosis. For additional suggestions see Dr. Carrington's "Fresh Air and How to Use It" ($1), National Association for the Study and Prevention of Tuberculosis, 105 E. 22d St., New York City.

31. Treatment of diphtheria. — But these germs do not have things all their own way. The cells of the body seem to know when an army of this enemy has entered their territory, and they at once set to work to produce substances that will neutralize or overcome the toxins formed by the diphtheria bacteria; these substances are known as *antitoxins.* When the disease is at its height, there is a fierce battle between the invading microbes with their toxins and the cells of the body fighting for their lives by means of their antitoxins. If the bacteria are victorious, death ensues.

In the year 1892 a most important discovery was made by a German bacteriologist named Von Behring. He found that it is not necessary for the human body to manufacture all the antitoxin it needs for its struggle with the diphtheria poisons, but that this substance may be taken from the blood of other animals that have produced it. For this purpose, healthy horses are now secured by city boards of health, and a small dose of diphtheria toxin is injected into their bodies; the next day a larger dose may be given with little or no ill effects; until, at the end of several months of this treatment, the animals can stand a quantity of the poison that would have proved fatal if given at an earlier time. For during all these days the horse has been having a very mild form of diphtheria, and the cells of his body have been producing and giving into the blood an amount of antitoxin much more than is needed to neutralize the diphtheria poisons the animal has received. Some of the blood is then carefully removed and allowed to clot. The liquid *serum* that oozes out of the clot contains the antitoxin, which is carefully prepared for injection into the body of human beings when diphtheria attacks them. And so our good friend the horse, without any permanent ill-effects to himself, has decreased the death rate formerly caused by diphtheria by 75 to 80 per cent.

32. Prevention of diphtheria. — We have learned something of the means by which we can combat this disease when once it has begun its attack. Antitoxin may also be administered to any members of the family who have been exposed to diphtheria, and it then becomes a means of preventing the disease. But it is much more important, as is the case with tuberculosis, to prevent all danger from attacks by this disease than it is to know how to cure it. Here again we find strong arguments for the enforcement of the rules against spitting, for living bacteria are often found in the throats of sufferers from what are thought to be ordinary sore throats. For this reason, too, children should be especially careful to avoid putting into their mouths pencils, coins, candies, or other objects that have been used by other pupils, for diphtheria germs have been frequently transmitted in this manner.

FIG. 16. — Typhoid bacteria.

33. Cause of typhoid fever. — Typhoid fever is a disease caused by the growth in the tissues of the intestines of rod-shaped bacteria. The typhoid bacteria have several hair-like projections something like long cilia (known as *flagella*), which vibrate rapidly and so enable the germs to move about (Fig. 16). These bacteria are practically always taken into the body through the mouth and thence into the intestines. "Food and drink are usually the vehicles which serve for the entrance of the bacillus, water and milk being probably the most frequent sources of infection. The latter is especially dangerous from the fact that the typhoid bacillus not only lives but multiplies in it. Water and milk, however, are only dangerous when they actually contain the typhoid bacilli which have entered into them from the excretions of

typhoid patients or those who have become typhoid carriers."[1] It has been proved over and over again that the common house fly is frequently the means by which typhoid fever is transmitted (**A. B.**, **43**), since these insects often alight on the excretions of typhoid patients, and then carry the germs on their hairy feet (**A. B.**, Fig. 40), and so infect the foods on which they alight.

34. Prevention of typhoid fever. — It is evident, then, that if the excretions from the intestines and kidneys of typhoid patients were thoroughly disinfected by carbolic acid or other germicides, the spread of typhoid fever would be very largely prevented. It must be borne in mind, however, that the bacteria of this disease continue to live in great numbers and to multiply in the intestines of some people who have had typhoid fever years after recovery from the disease, and these people are the so-called "typhoid carriers."[2]

One of the most difficult problems that formerly confronted armies was that of preventing typhoid infection. In the Mexican War and in the Civil War the armies on both sides paid frightful toll to this dread disease, and even in the Cuban War, five thousand men in the United States Army died of typhoid fever or other fly-borne diseases, while only three hundred were killed by Spanish bullets. Sanitary camps, however, have greatly improved the situation, and in recent years an anti-typhoid vaccine, somewhat like that used in the prevention of smallpox, is injected as a means of prevention, and the results of the use of this vaccine have been most favorable. The improvement in army health is strikingly shown by comparing figures for two army divisions of about the same size, one at Jacksonville, Florida, during the Spanish-American War in 1898, the

[1] Quoted from article on typhoid fever, in New International Encyclopedia, copyrighted 1903 by Dodd, Mead, and Co.
[2] See footnote, p. 39.

other at San Antonio, Texas, during the 1911 maneuvers on the Mexican border.

	Jacksonville 1898	San Antonio 1911
Number of soldiers	10,759	12,801
Number cases typhoid (certain and probable)	2,693	1
Number of deaths from typhoid fever	248	0
Number of deaths from all diseases . .	281	11

35. Water supplies. — In country districts each house usually has its own well, and so the family becomes accountable for its own water supply. In this case great care should be taken to place the well in such a position that none of the drainage from the house or barn can soak through the soil into the well-water. Those who live in large towns and cities almost always obtain their water supply from a common source. This sometimes becomes contaminated by typhoid and other germs, and a disease epidemic then follows. Hence, if there is any doubt as to the purity of a water supply, boards of health should notify the householders, and the water, when used for drinking purposes, should then be boiled and kept in bottles on ice until used.

36. Milk supplies. — Many families in rural communities keep their own cows, and so they can be sure of clean milk if they only take the necessary trouble. Cows, like human beings, need plenty of light, air, wholesome food, and clean surroundings. If any of these are wanting, the animals are likely to become diseased, and the milk is then affected. Great care should be taken also at milking time to see that

the surface of the body of the cow, especially about the flanks and udder, are brushed and wiped with a moist cloth, and that the hands and clothing of those who milk are kept clean; otherwise enormous numbers of microbes will fall into the milk. No one who has any infectious disease should be allowed to have anything to do with the care of cows or of milk until he has completely recovered. Over and over again epidemics of diphtheria, scarlet fever, typhoid,[1] and tuberculosis in infants have been traced along the routes of careless milkmen.

Those who live in cities, however, are wholly dependent for milk upon sources they know nothing about. The milk that is consumed in New York City, for instance, comes from over 40,000 dairies scattered through six different states. It is, of course, impossible to make any proper inspection in such a wide field. The New York Board of Health is doing all it can in this respect, and so far as possible it prevents dirty and dangerous milk from coming to the city. The only path of safety, however, lies in the careful Pasteurization of milk and cream that are used for drinking purposes, especially by young children. In communities where Pasteurization has been tried at all generally, there has been a surprising decrease in the percentage of sickness and death from intestinal diseases, especially in the summer time and among young children. The instruction given by boards of health to mothers and to older children as to the care of the young during the hot months has also helped to save the lives of a large number of infants.

[1] A sudden increase in the number of cases of typhoid fever in New York City in 1909 was found to be entirely due to milk furnished by a dairyman in a town in New York State. He had recovered from typhoid fever in 1864, but still carried infection in his body and passed an enormous number of the germs of the disease.

37. Smallpox and vaccination. — Smallpox was once so common that scarcely one person in a hundred escaped it. It was introduced into America by the Spaniards, it destroyed 3,500,000 people in Mexico, and spread with frightful rapidity throughout the New World, until in 1733 it nearly depopulated Greenland. Mankind is indebted to Dr. Edward Jenner (Fig. 17), an English physician, who in 1796 proved that vaccination is a sure method of preventing the disease. In vaccination our bodies receive germs that originally came from smallpox, but which have been so modified that they cause a mild form of disease very different from smallpox itself. The cells produce some form of antitoxin which is effective protection when we are exposed to the disease. This kind of protection does not last indefinitely, however, and every person should make sure that successful vaccination is performed at least once in ten years, and oftener than that if cases of smallpox develop in the community in which he is living. If a person has been actually exposed to the disease, he should be vaccinated immediately.

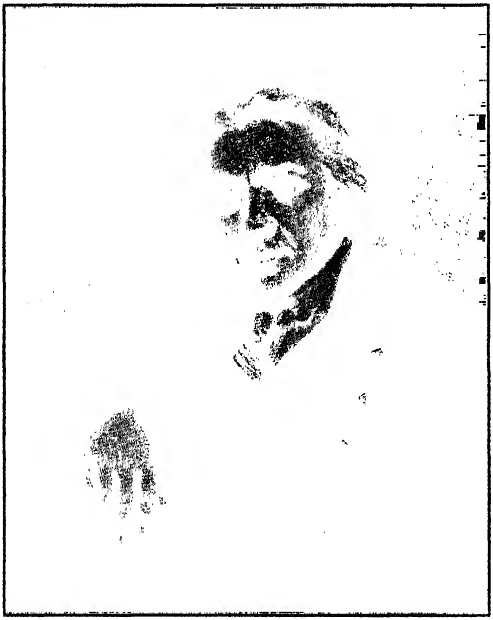


Fig. 17. — Dr. Edward Jenner, English physician. Born 1749. Died 1823.

(From International Enclyclopedia. Courtesy of Dodd, Mead & Co.).

Since the introduction of compulsory vaccination, smallpox is becoming very rare.

38. Hydrophobia and the Pasteur treatment. — Hydrophobia, or rabies, is a disease due to the bite of a mad dog, cat, or wolf. Until the latter part of the nineteenth century the only known method of treating this disease was that of burning out or cauterizing the wounds with hot irons or nitric acid. After a long series of investigations, however, Louis Pasteur (Frontispiece), a French scientist, made known to the world the so-called Pasteur treatment (1885). Pasteur found that the disease was located in the spinal cord, and that, if pieces of the spinal cord of a rabbit which had died of hydrophobia are allowed to dry in the air, the germs gradually lost their virulence. He therefore began the treatment of patients who had been bitten by mad dogs by first injecting beneath the skin an emulsion made from the spinal cords which had been dried for fourteen days. Each day for twenty-one days an injection was made from a cord that had been dried for a shorter time. Since hydrophobia usually does not develop in human beings for two weeks to four months after the bite of a mad dog, the cells of the body by this Pasteur treatment gradually acquire the power to resist the hydrophobia toxins, and so the disease is prevented, if the wound is cauterized at once and treatment begun immediately. The cauterization is of value even after a delay of twenty-four hours.[1]

39. The cause and prevention of other diseases. — The germs that cause scarlet fever, yellow fever, measles, whooping cough, and infantile paralysis have not as yet been discovered. Since, however, they are all infectious diseases like tuberculosis and diphtheria, they must be due to some form of microbe. Those in yellow fever, measles, and infantile paralysis are so small that they pass through stone filters.

[1] The authors are much indebted to Dr. W. H. Park, Director of the Laboratory of the Board of Health of New York City, for his suggestive criticism of the sections relating to disease-producing bacteria.

These cells are therefore too small to be seen by the most powerful microscopes.

The life history and method of transmission of the microscopic animal that causes malaria has already been discussed in connection with the study of the Anopheles mosquito (**A. B., 40**). Likewise, it has been demonstrated beyond a cavil that infection from a yellow-fever patient can only be brought about through the agency of the Stegomyia mosquito. Hence, to eradicate these diseases entirely, we need only to exterminate all Anopheles and Stegomyia mosquitoes. Sleeping sickness is a dread disease of the tropics which is due to a kind of Protozoan something like a paramecium.

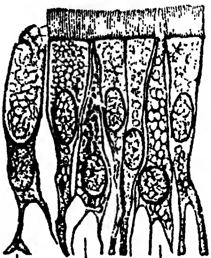


FIG. 18. — Ciliated cells from the windpipe.

40. Safeguards of the body against disease. — In the first place, the tough outer skin, as long as it is unbroken, forms a most effective barrier to the entrance of bacteria, except at the mouth and nose openings. Each of the nostrils is guarded by hairs that collect a large number of dirt particles. On the mucous membrane lining the nose and throat still other bacteria are caught, and the cells which line the windpipe are furnished with cilia, which lash upward (Fig. 18) and tend to expel the germs that may have gone past the outer lines of defense that we have named. If the bacteria enter the stomach and intestines in a living condition, many of them are digested with the food. And even though the invading microbes finally reach the interior of the cells of our lungs, or muscles, or brain, we can still rely upon the antitoxins which the cells of a healthy human

body are ever ready to produce. In the case of many of the contagious diseases, like scarlet fever or smallpox, these antitoxins remain for a considerable time in the blood to make us immune against a second attack. The white corpuscles, too, are a sort of cavalry troop, ready to pounce upon the bacteria and either devour them or carry them off from the body (Fig. 12, *A*). An optimistic view of life and freedom from worry are undoubtedly very important factors in keeping the body in a state of vigorous health.

41. Topics for biology composition.[1] — Optional Library Work. Consult the local health authorities, Allen's "Civics and Health," Bulletins of U. S. Department of Agriculture, New International or other Encyclopedia, and other sources, and prepare in your notebook a composition on one or more of the following topics: —

1. The Work of the Board of Health.
2. The Work of the Tenement House Commission.
3. How a City May Be Kept Clean.
4. A Visit to a Model Dairy.
5. City Milk Inspection.
6. A Hygienic House.
7. Helpful Bacteria.
8. City Playgrounds and Parks: Their Use and Abuse.
9. How the Study of Bacteria Can Help Us in Our Homes.
10. Sleeping in the Open Air.
11. A Visit to Ellis Island: How the Commission Cares for Immigrants.
12. The Responsibility of the Individual for Public Health.
13. An Ideal School Infirmary.
14. The Work of the Consumers' League.
15. Methods of Sewage Disposal.
16. The City Water Supply.

[1] The authors are indebted to Miss Edith Read of the Morris High School for the following list of composition topics.

CHAPTER III

FOODS AND THEIR USES

I. Food Substances found in the Human Body

42. Composition of the body. — Many careful analyses have been made of the composition of the human body, and these analyses have shown that our bodies are made of the same kinds of materials as those found in plants; namely, proteins, fats, carbohydrates, mineral matters, and water.

43. Proteins. — The most important substances in the living body are the proteins. As we have already learned,[1] proteins are essential constituents of the protoplasm of every plant cell, and this is likewise true of the cells in animal and human bodies.

44. Fats and carbohydrates. — The amount of fat in the body varies greatly in different individuals, but it is always present in some quantity. Muscle, however lean, contains particles of fat; fat constitutes a small percentage of the blood; it fills the spaces in the interior of bones; and it is often deposited in considerable quantity in the deeper layers of the skin. In the blood and in other animal tissues we find some of the carbohydrate called grape sugar. Another carbohydrate known as animal starch, or *glycogen*, is found in the liver and in the muscles.

45. Mineral matters. — Mineral matters are found in the greatest quantities in the bones and the teeth. When

[1] **43**, "Plant Biology."

we burn bones, about one third of the weight disappears, the remaining two thirds being bone ash, which is the mineral matter. Every part of the body, however, contains some mineral ingredients; for when muscle, liver, brain, or blood is burned, there remain some traces of ash in each case.

46. Water. — The great importance of water in the composition of the human body is evident from the fact that this compound forms about 62 per cent of the weight of an adult. Hence, if all the water were removed from the body of a man weighing one hundred and fifty pounds, the solids that remained would weigh less than sixty pounds. The different organs vary greatly in their percentages of water; bones contain about 22 per cent, muscles have 75 per cent, and the kidneys 82 per cent.

II. The Necessity for Foods

47. Necessity of foods for growth. — During the earlier years of life, as we all know, the human body rapidly increases in weight. A child at birth usually weighs seven to eight pounds, whereas the weight of a fully grown man is often one hundred and fifty pounds or more. Hence during a lifetime there is often a twentyfold increase in weight. To provide for this increase or growth a large amount of new material must of course be taken in by the human being, and this material is supplied by the food.

48. Necessity of foods for repair and for the production of energy. — On the other hand, it is not difficult to prove that throughout life the body tends constantly to decrease in weight. For instance, if one were weighed on accurate scales immediately after eating and then again after several hours had elapsed and before food or drink had been taken, a decrease in weight would be noted. Still more striking is

the loss of weight due to abstaining from food because of illness or other reasons.

It has been found too that when one is engaged in very active exercise, such as playing tennis or football, the loss of weight is greater than when one remains quiet. How, then, can we account for the loss of weight in all the cases that we have been enumerating? We all know that during violent activity considerable quantities of perspiration are given off from the skin, and this has been proved to be true at all other times, though to a less extent. It has also been demonstrated that many waste materials are given off from the lungs, the organs of digestion, and the kidneys.

We have now accounted for the constant loss of weight in our bodies, but we have still to ask ourselves how these waste substances are produced in the body. The two commonest wastes of the body are carbon dioxid and water. These are produced by the oxidation of the carbon (**P. B., 80**) and the hydrogen in the foods. This has also been proved to be true in animals and in the human body.

49. Definition of a food. — The three most important uses of foods have been suggested in the preceding sections. Hence we may say that a *food is any substance that yields material for the repair or growth of the body, or that supplies the fuel used by the body for producing heat, or power to do work.* It should be understood, however, that no substance should be regarded as a food if it injures the body while supplying materials for growth, repair, or the production of energy.

III. The Composition of Foods

50. To determine the food substances present in milk. — Laboratory demonstration.

1. Shake a bottle containing milk and cream and pour a

small amount into a test tube; add a little strong nitric acid, and boil.

a. Describe what was done.

b. What change in the color of the milk do you observe?

c. What food substance do you therefore conclude to be present in milk?

2. Place a drop of the "mixed milk," used in 1 above, on paper, and allow the paper to dry over a warm radiator. Hold the paper to the light. What kind of food substance is present in considerable quantity in the milk? How do you know?
3. Add a few drops of iodine to some milk. What is the result, and what is your conclusion?
4. Test another sample of milk with Fehling's solution. State the result and your conclusion from the experiment. The sugar found in milk is known as *milk sugar*, and when it is heated with Fehling's solution, it is changed to grape sugar.
5. Heat a half spoonful of milk, and hold over it a clean, dry tumbler. What nutrient does this experiment prove to be present? Why?
6. (Optional.) Evaporate to dryness the spoonful of milk, and then burn the solid residue over a very hot flame. Does all the solid disappear, or is something left on the spoon? What is your conclusion as to the presence or absence of mineral matter in milk?
7. As a conclusion from all your experiments, state what food substances or *nutrients*[1] are present in milk, and what food substances are absent.

51. The composition of other foods. — Our study of milk has shown us that this food is composed of the same

[1] In our study of plant biology we called the compounds named in this paragraph *food substances* rather than *nutrients*, for botanists regard the simpler compounds (carbon dioxid, water, and mineral matters) that plants obtain from the water and air as the nutrients of the plants. By some writers water is not regarded as a nutrient; since, however, it is an essential constituent of protoplasm, it may well be named among the nutrients.

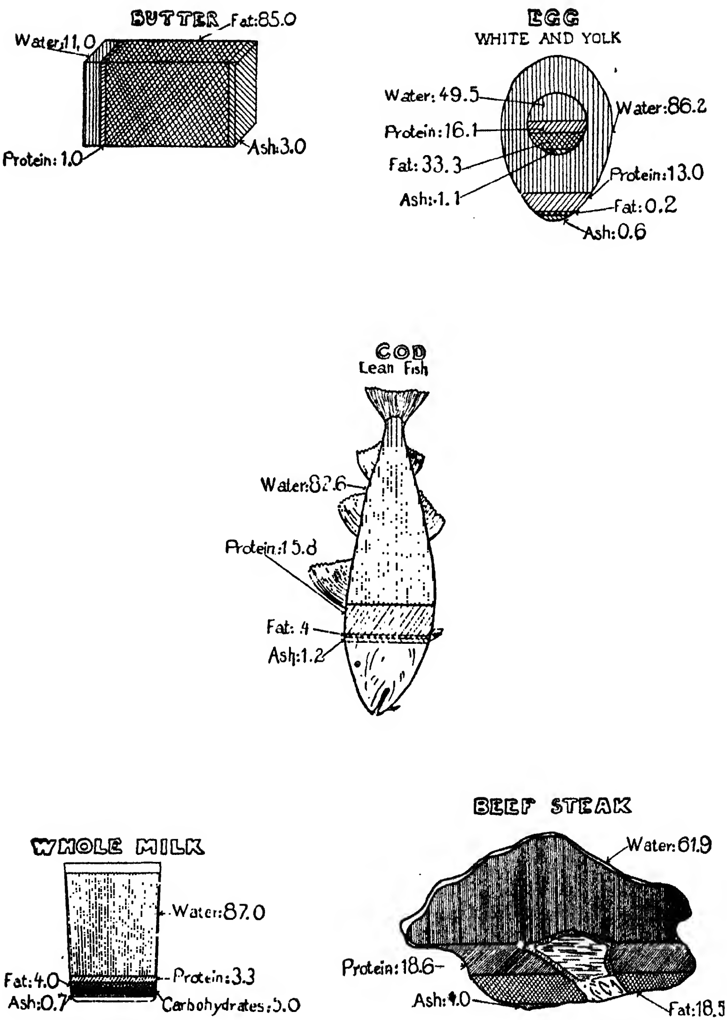


FIG. 19.—Composition of common animal foods. (Drawn from Charts of U. S. Dept. of Agriculture by Mabelle Baker.)

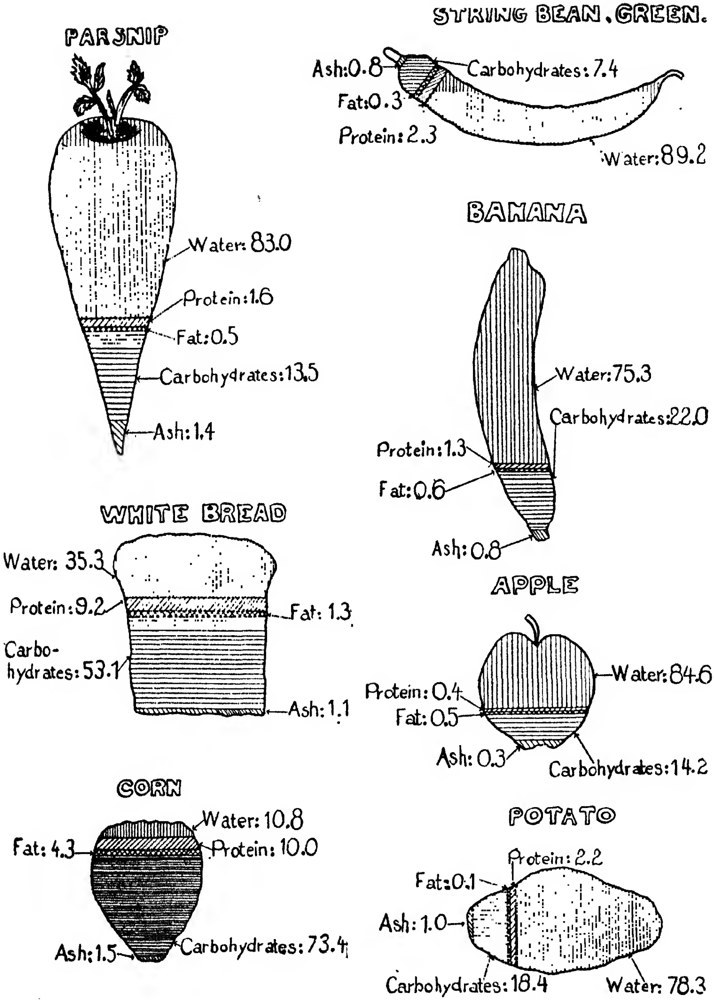


FIG. 20.—Composition of common vegetable foods. (Drawn from Charts of U. S Dept. of Agriculture by Mabelle Baker.)

kind of food substances that we found in plants; and this is what we might expect, since the cow is wholly dependent upon grass and other vegetable foods. Indeed, when we analyze any other animal foods that we eat, we find that all consist of one or more of the food substances which closely resemble those that we have been studying in plant biology. In Figures 19 and 20 are represented not only the various nutrients found in some of our most common foods, but also their relative proportions in percentages.

52. Composition of various foods. — (Home study.)

1. Name the foods represented in Figures 19 and 20 that are derived from animals; name those obtained from plants.
2. Which of the two classes of foods, named in 1 above, has on the average the larger percentage of protein?
3. In which of these two classes do you find the larger amount of fats?
4. Which class has the larger percentage of carbohydrates?
5. What, then, are the principal differences in the composition of animal and vegetable foods?
6. Name the various food substances found in one animal food and in one vegetable food, giving in each case the percentage of each nutrient.

IV. Uses of the Food Substances

53. Uses of the food substances to plants and animals. — In our study of green plants we learned that these living organisms can manufacture the food substances they need from the simple compounds (water, carbon dioxid, and mineral matters) found in earth, air, and water, and that these food substances are used for the making of protoplasm and the liberation of energy. Animals and human beings, on the other hand, since they cannot make their foods, are

either directly or indirectly dependent on plants for their food supply. They use these food materials, however, for the same purposes as do plants. The use of the individual food substances will now be considered.

54. Uses of proteins. — Protein is an essential constituent of plant protoplasm (**P. B., 43**). This class of nutrients is also essential for the growth and repair of the living substance in muscle, nerve, and all other tissues of the human body. Proteins may also be oxidized in the body and give heat and muscular energy.

55. Uses of fats and carbohydrates. — The chief fuel ingredients of food, however, are the fats and carbohydrates. Most of the fat in our foods is probably oxidized soon after it reaches the cells to furnish heat and power, and this class of nutrients possesses two and a half times the fuel value of any other kind of food substance. This is the reason why the inhabitants of arctic countries eat such large quantities of fatty foods.

The starches and sugars of bread, potato, fruits, and milk are also used as fuel. The fat which we stated (**44**) is stored in various parts of the body, is derived partly from the carbohydrates and partly from the fats in our food, and this acts as a reserve fuel. That portion of the fat which is stored in the deeper layers of the skin helps to keep our bodies warm by preventing the escape of heat.

56. Comparison of uses of the nutrients. — It is evident that the three nutrients thus far studied may be used to supply the body with energy. If our diet is deficient in any one of the three, the others supply the need, and are burned instead. For growth and repair, however, proteins are absolutely essential; neither carbohydrates nor fat can be transformed

into this essential ingredient of protoplasm. Hence, an animal soon dies if it is not supplied with proteins.

If a machine is to do a large amount of work, it must be large enough and strong enough, and must have plenty of fuel. This is true of the body machine. A man who does hard work, and a good deal of it, needs plenty of proteins in his food to build up his tissues and keep them in repair, and plenty of fats and carbohydrates for fuel.

57. **Uses of mineral matters and water.** — The mineral matters like phosphate and carbonate of calcium and magnesium are necessary for making bones and teeth, and for the making of protoplasm (**P. B., 43**). Salt is used in large quantities by all civilized nations; it makes food more palatable and it is important in the making of digestive fluids.

Water is an essential constituent of protoplasm, and hence the body needs it constantly. Water also aids in dissolving foods. A considerable amount is supplied by the water contained in some of our solid foods, and we get the rest from the water and other beverages that we drink.

V. Cooking of Foods

58. **Importance of proper cooking.** — Some of our foods, like milk, nuts, and fruits, are eaten without being cooked. The great majority, however, before they are taken into our bodies are changed considerably. It is important for us to learn the essential principles of good cooking, since food, as often prepared, loses much of its flavor, becomes more or less indigestible, and is deprived of a considerable percentage of its nutrition.

59. **Reasons for cooking animal foods.** — In civilized communities meats and other animal foods are usually cooked by broiling, roasting, boiling, or frying. The reasons for cooking the flesh

of animals are these: (1) proper cooking loosens and softens the fibers, thus preparing the meat for mastication and for the action of the digestive juices; (2) the heat kills the harmful bacteria and other parasites (*e.g.* tapeworms) that are sometimes found in foods of animal origin; (3) cooking makes the meat more attractive in appearance and often improves its flavor; and (4) cooked meat is more *completely* digested. It is probably true, however, that raw or partly cooked meats are more *easily* digested.

60. Frying. — If meats are fried, the skillet should be very hot, so that the surface of the meat may be coagulated at once, thus preventing the escape of nutrients and the entrance of fats. Frying usually involves the use of additional fats, and since frying tends to make foods indigestible, this is doubtless the poorest method of cooking meat.

61. Soups. — If we wish to obtain nutritious soups, the meat should be cut into rather small pieces and first put into cold water to which a little salt has been added. A small proportion of the proteins, and large amounts of so-called "extractives," or flavoring matters, are drawn out by the water and salt, and since the meat is in small pieces, a considerable proportion of the mineral matter is thus dissolved. When we warm the mixture, we cause the fats to melt, and when it is boiled, much of the tough connective tissue is made more or less soluble by being turned into gelatin. The soups thus obtained are made more palatable by the addition of condiments.

The meat which is left after the soup has been prepared is more or less tasteless. Only small percentages, however, of the nutrients have been withdrawn; hence the soup meat should not be thrown away, but should be used as described in **71**.

62. Stewing. — It is unfortunate that stews are not more highly regarded in American families, for by this method of preparing animal foods all the nutritive ingredients are utilized. To make a good stew the meat should be cut into rather small pieces and placed in cold water. Some of the flavoring matters and soluble proteins

pass out into the broth, making it rich and nutritious. When the stew is allowed to simmer for several hours on the back of the stove, the meat itself becomes tender and readily digestible. The addition of vegetables makes it a most nourishing and palatable dish.

63. Boiling meats. — When the meat itself is to be eaten, and the broth is not to be used, the whole piece should be plunged into boiling water for a few moments. In this way the protein on the surface is quickly coagulated, and the crust thus formed prevents the loss of the meat juices. The temperature of the water should then be reduced somewhat below the boiling point by pushing the kettle toward the back of the stove, and the meat should then cook slowly until it is done. A piece of meat, when cooked in this way, is tender and juicy throughout. If, however, the water is kept at the boiling point (212° F.), the meat may be easily torn apart, but the fibers are found to be hard and stringy.

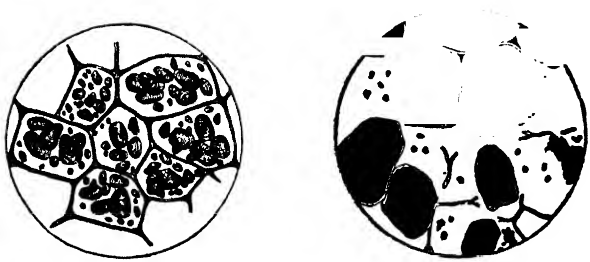
64. Roasting and broiling. — The best method of cooking the flesh of animals, if the broth is not desired, is by roasting or by broiling, since smaller percentages of the nutrients are lost than is the case in boiling. The outer layer of protein must, however, be coagulated at once, and for this purpose a very hot fire is needed.

When the piece to be roasted is small, the high temperature should be maintained until the meat is cooked. A large roast, on the other hand, after the outer covering has been coagulated, requires a slower fire and a longer time; meat is not a good conductor of heat, and a hot oven would scorch the outside before the central mass could become thoroughly cooked. A better crust is formed on the outer surface of the roast if the meat juices in the pan (mostly fat) are frequently poured over the surface of the roast. This is called "basting."

65. Reasons for cooking vegetables. — The starches, which are present in large quantity in foods of vegetable origin, are usually inclosed in cells, the walls of which are formed of indigestible cellulose. Hence, before starch can be digested, it must be freed from this cellulose envelope. This is largely accomplished by cooking,

which causes the starch grains to swell. The cell walls are broken open in this way, and when the grains burst, a larger surface is exposed to the action of the digestive juices (Figure 21). This is strikingly shown in popping corn. The crust of bread is more easily digested than the softer parts, and toasting bread increases its digestibility, because this browned starch (sometimes called soluble starch) requires less change before it can be used by the body.

66. Boiling vegetables. — Experiments have shown that a good deal of nutriment is lost by boiling vegetables in water. Much of



A B

FIG. 21. — *A*, cells of raw potato with starch grains inclosed in the cellulose walls. *B*, cells of a potato well steamed and mashed; starch grains have been burst by the heat.

this waste may be avoided, however, if one heeds the following directions: (1) vegetables should be cooked as far as possible in their peels, for these outside coverings keep the sugar, proteins, and mineral matters from being drawn out by the water; (2) if the vegetables must be peeled and cut up, the pieces should be relatively large, as a smaller surface is thus exposed to the water; (3) the amount of water should be as small as possible, and the vegetables should be cooked rapidly, in order to give less time for the solvent action to take place.

67. Bread making. — When bread is made, water (or milk), butter, salt, sugar, and yeast are added to flour. After the mixture has been stirred together, a sticky mass of dough is formed, which, in

a warm place, begins to rise. This is due to the fact that the yeast cells change the sugar into alcohol and carbon dioxid. Bubbles of gas are thus imprisoned in the sticky dough. While expanding and seeking to escape, the gas makes the solid mass porous. After the bread has risen sufficiently, it is kneaded in order to break up the large bubbles and in order to distribute the gas throughout the dough. When the bread is baked, the alcohol and carbon dioxid pass off into the air, leaving the bread light and digestible.

VI. Food Economy

68. Importance of food economy. — It is said that in a large proportion of American families more than half the total income is spent for food, and that the remainder of the income must serve for rent, fuel, clothing, doctor's bills, and other expenses. Hence, any saving that can be made in the annual food bill of a family should result in a surplus which may well serve as a nucleus of a saving's bank account, or may be used in improving the home surroundings or in securing wider means of education and enjoyment. The average American, however, is far from economical in the matter of foods. In the first place there is often extravagance in the purchase of food, and in the second place foods are frequently wasted in the home.

69. Comparative cost of foods. — (Home study.) The chart shown in Figure 22 exhibits (1) the cost price of each of the foods represented, (2) the weight of the food that may be purchased for 25 cents, and (3) the weight of the solid food substances (except mineral matters) that may be purchased in each food for 25 cents. Note at the top of the chart the short vertical lines that indicate 1 pound, 2 pounds, etc., of solid nutrients; hence, if 25 cents is spent for wheat flour, about $\frac{3}{4}$ of a pound of protein can be secured, $\frac{1}{4}$ of a pound of fat, and about $6\frac{1}{2}$ pounds of carbohydrates.

PROTEIN FATS CARBOHYDRATES

THE HEAVY BLACK LINES IN THE CHART BELOW INDICATE THE RELATIVE FUEL VALUE IN ONE POUND OF EACH OF THE NUTRIENTS

		PRICE PER POUND.	FOOD MATERIALS FOR 25 CENTS.
		CTS.	LBS.
ANIMAL FOODS	BEEF, SIRLOIN	25.0	1.00
	BEEF, ROUND	15.0	1.67
	BEEF, NECK	6.0	4.17
	MUTTON, LEG	22.0	1.14
	HAM, SMOKED	16.0	1.56
	SALT PORK, VERY FAT	12.0	2.08
	CODFISH, FRESH	8.0	3.13
	CODFISH, SALT	7.0	3.57
	MACKEREL, SALT	12.0	2.08
	OYSTERS, 35 CTS. QUART	18.0	1.43
	EGGS, 25 CENTS DOZEN	14.7	1.70
	MILK, 7 CENTS QUART	3.5	7.14
	CHEESE, WHOLE MILK	15.0	1.67
	CHEESE, SKIM MILK	8.0	3.13
	BUTTER	30.0	0.83
VEGETABLE FOODS	SUGAR	5.0	5.00
	WHEAT FLOUR	3.0	8.33
	WHEAT BREAD	7.0	3.57
	CORN MEAL	2.5	10.00
	BEANS	5.0	5.00
	POTATOES	1.2	20.00
	STANDARD FOR DAILY DIET FOR MAN AT MODERATE WORK	AMERICAN	

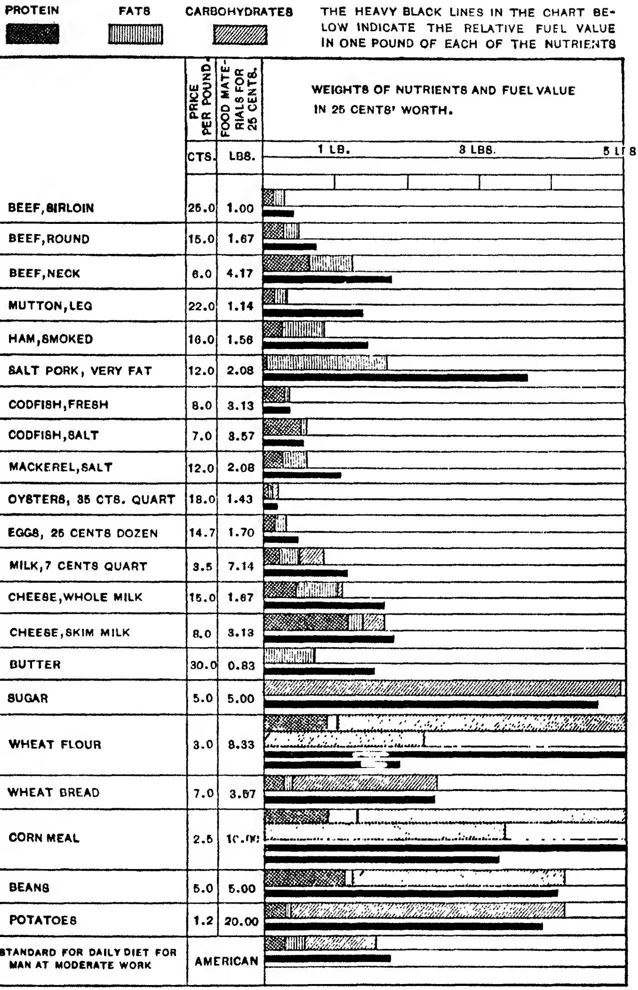


Fig. 22. — Economy in the purchase of foods. Prices in this chart were those in the year 1900. Compare with prices to-day. (U. S. Department of Agriculture.)

1. Name the foods represented in Figure 22 that are derived from animals; name those obtained from plants.
2. On the average, can larger amounts of the animal or of the vegetable foods represented on the chart be purchased for 25 cents?
3. Bearing in mind the relative work and expense in producing animal and vegetable foods suggest some explanations for the answer you have given to question 2.
4. Which one of the foods on the chart would you buy if you wished to get the largest amount of solid nutrition for 25 cents; that is, which food is the most economical?
5. From which kind of food would you get the smallest amount of solid nutrients? Name other foods on the chart which are more expensive per pound than the one that you have just named.
6. Which of the three kinds of beef named on the chart would be the most economical for soup or stew?
7. Name three classes of food substances needed in the diet of the average American engaged in moderate work (see last line on the chart), and estimate the weight of each that is needed during a day.
8. Which food on the chart comes the nearest to supplying in the right proportions all the nutrients named in 7? In the food you have named which kind of food substance is not present in sufficient proportion?
9. Why is it better to eat a variety of foods rather than any one kind?
10. Suggest a reason why meat and potato should be eaten together; bread and butter.

70. Economy in the purchase of foods. — The animal foods, we have just learned, are considerably more expensive than the staple foods of vegetable origin. Hence, in an economical household the proteins needed by the body should be largely obtained from vegetable foods like bread, corn meal, and beans. If this plan were followed, a con-

siderable saving in the year's expenses might be effected. Figure 22 shows the weights of different food materials that may be purchased for 25 cents. On comparing the two meats at the top of the chart, one can see that a greater fraction of a pound of solid nutriment may be obtained by spending 25 cents for round steak than could be secured by the purchase of sirloin. Yet the latter is bought even in very poor families. From oysters one gets less of the solid nutrients than from any other food represented on the chart; therefore, if one's income is small, this kind of food should be regarded as a luxury, seldom purchased except in case of sickness.

71. Economy in the use of foods. — In discussing the cooking of foods, we suggested some of the ways by which the loss of nutritive ingredients may be prevented. We waste foods, however, in other ways; for instance, we often throw away bones and gristle, regardless of the fact that they contain a considerable percentage of protein, gelatin, and fat from which one might make a nutritious soup. It has been found that large proportions of the food materials still remain in a piece of meat after it has been used for soup, even though it is more or less tasteless. This meat should not be thrown away, however, but should be chopped up and combined with vegetables and condiments to make a hash. The garbage pails of most kitchens receive far too large a percentage of the food that is bought for the household, and many a dollar could be saved for other purposes if more care were exercised to prevent this waste.

The food problem, then, for the healthy human being is this — *how to obtain the largest amount of good, nutritious food for the least money.* To this problem an intelligent housekeeper, if she can be led to see the importance of the subject,

will devote considerable thought. This problem cannot be solved, as we have seen, by consulting market prices only, for often the highest-priced foods contain small percentages of the nutrients. Neither can we be sure of a good supply of foods by following our tastes. To many people cakes and sweetmeats are more appetizing than sandwiches and cereals. Yet it is the latter that usually supply the available proteins, at a lower cost.

The composition of various foods can be found only by chemical analysis, and their nutritive value can be determined only by experiment. Fortunately these analyses and experiments are being carried on by the United States government. The results are published in the Bulletins [1] of the Department of Agriculture, Washington, D.C., many of which will be sent free to any address.

VII. Daily Diet

72. Amount of each nutrient required. — Many investigations have been carried on, in this country and in Europe, to determine the amount of each kind of nutrient needed per day for the work of the body. The conclusions that were drawn from this study are represented on the last line of Fig. 22. According to these conclusions the average American, when doing moderate work, requires about one fourth of a pound of proteins to provide for the growth and repair of the body, and a quarter of a pound of fat and a pound of carbohydrates to furnish the needed energy.[2] This

[1] The most suggestive of these publications are "Foods, and the Principles of Nutrition," "Meats: Composition and Cooking"; "Milk as a Food"; "Fish as a Food"; "Sugar as a Food."

[2] Recently, however, at the Scientific School of Yale University, some very careful experiments have been performed by Professor Chittenden which seem to prove that this quarter of a pound of pro-

is about the amount eaten by a man of average appetite. In order to secure a heathful diet, the general principles stated in the following paragraphs should be borne in mind, by an adult or by a growing boy or girl.

73. Necessity for a mixed diet. — A sufficient variety of foods should be eaten at each meal to obtain all the nutrients needed. In **69** we learned that in none of the foods on the chart are the nutrients in the right proportions. Cow's milk comes the nearest to being a perfect food, but its percentage of carbohydrates is too small. If we were to feed on meat alone, we should get too large an amount of proteins; while most of the vegetable foods are lacking in fats. Hence, a well-balanced diet should consist of a mixture of many kinds of foods. Such a diet will supply not only the proteins, fats, and carbohydrates, but also the mineral matters so necessary in the development of the bones and teeth, and in the making of living substance. In fact, some foods, such as spinach, are valuable chiefly on account of the mineral matters which they contain. If the appetite is normal, one is fairly sure to secure the nutrients in approximately the right proportions.[1]

tein for each day is considerably more than the body really needs. Dr. Chittenden experimented on five of the Yale University professors, on thirteen soldiers of the United States army, and on five of the best athletes at Yale; he found that all agreed that they could do better physical and mental work, and do it without any loss of weight, when they had become accustomed to taking less than half their ordinary amount of proteins. In several instances rheumatism, biliousness, and other derangements of the body were cured by this restricted diet. "There is no question, in view of our results," says Professor Chittenden, "that people ordinarily consume much more protein food than there is any real physiological necessity for, and it is more than probable that this excess of food is in the long run detrimental to health, weakening rather than strengthening the body, and defeating the very objects aimed at."

[1] It is desirable that pupils prepare a list of the kinds of foods and beverages, stating quantity of each, that formed their diet on the

74. Avoidance of indigestible foods. — Frequently individuals find that they cannot eat certain kinds of foods, *e.g.* cheese, honey, cucumbers, without discomfort. Hence, in selecting their diet these foods should not, of course, be eaten. Foods that are hard to digest, such as fried foods, heavy bread, or pastry, should be avoided, especially by growing girls and boys.

75. Sugars as a part of the diet. — Carbohydrates, we have found, are essential constituents of our foods. If, however, sugars are eaten between meals, too much of this kind of food substance is likely to be consumed, the appetite for other foods is lessened, and digestive disturbances are likely to follow. Consequently the pastry and confectionery that are eaten should form a part of dessert.

76. Review of Foods

Name of Nutrient	Test for Nutrient	Uses of Nutrient	Foods Containing Nutrient
Protein (albumin, nitrogenous food).	Coagulates when heated. Turned to yellow color by nitric acid.	Necessary for the manufacture of protoplasm. When oxidized releases energy.	Meat, eggs, milk, cheese (among animal foods), and beans, peas, oatmeal (among vegetable foods).

three meals of some stated day. These menus should then be read and discussed by teacher and pupils, and such suggestions for improvement should be made as may seem necessary.

Name of Nutrient	Test for Nutrient	Uses of Nutrient	Foods Containing Nutrient
Starch.	Turned to a blue color by iodine solution.	Changed to sugar, source of energy, and may be transformed into body fat.	Vegetable foods (especially cereals).
Sugar.	Fehling's solution is turned orange or red when boiled with grape sugar.	Source of energy. Transformed into body fat.	Vegetable foods (especially fruits); milk sugar is found in milk.
Fats (or oils).	Make translucent spots on paper. Dissolved by ether or benzine.	Source of energy. Transformed into body fat.	Animal foods (especially butter, pork, cheese), vegetable foods, as nuts, cocoa, chocolate.
Mineral matters.	Left as ash after food is burned.	Help to form bone, teeth, and other tissues. Aid in digestion.	Common salt; mineral matters in most vegetable and animal foods.

CHAPTER IV

STIMULANTS AND NARCOTICS

I. Definitions

77. Stimulants. — In the preceding chapter we discussed food substances, and these, we learned, yield material for the repair or growth of the body, or supply the fuel necessary for producing energy in the body. But in addition to the various nutrients that may be used for one or all of these purposes, we often take with our food certain substances that are not useful to any considerable extent in any of these ways. As examples of such substances, we may mention spices. Such substances add an agreeable flavor to our foods, and so stimulate our appetites; hence, they are known as *stimulants. A stimulant is any agent that temporarily quickens some process in the body.* The most common stimulants are tea, coffee, and alcohol.

78. Narcotics. — Another class of substances that we sometimes use has an effect directly opposite to that of stimulants. Ether, morphine, and chloroform, for example, do not quicken any process in the body as do stimulants, but, on the contrary, lessen the degree of activity. Any compound that acts in this way is called a *narcotic. A narcotic is any substance that directly induces sleep, blunts the senses, and in sufficient amounts produces complete insensibility.*

II. Beverages

79. General effect of tea and coffee on the body. — The effect of tea and coffee on the body is due to the presence of essentially the same *stimulant* in both (caffein), which acts largely on the nervous system. In both tea and coffee, as they are usually prepared, is another substance known as *tannin*. This chemical, when obtained from the bark of certain trees, is used in tanning or hardening leather. When tannin is taken into the stomach, it is found to injure the mucous membrane and to retard digestion.

80. The preparation of tea and coffee. — To prepare tea properly, boiling water should be poured upon tea leaves, and the infusion allowed to stand only a few minutes before pouring. Tea should never be put on the stove to boil, for two reasons: in the first place, by this treatment the delicate taste and odor of the beverage are lost; and in the second place, if the tea infusion is boiled, a considerable quantity of the tannin is dissolved by the water. Obviously the tea grounds should not be used a second time.

Most that has been said in regard to tea applies equally well to coffee, except that in the preparation of coffee the infusion should be put on the stove and allowed to come to a boil; it should then be poured out, and should not stand on the coffee grounds; otherwise the tannin will be extracted. Coffee is best prepared by the use of a percolator, since in this utensil the water is continuously forced over the ground coffee.

81. The use and abuse of tea and coffee. — "When properly made, tea in moderation is a wholesome, agreeable, and refreshing stimulant beverage, particularly grateful in conditions of mental or physical weariness. Used in

excess, it exerts a harmful influence upon the nervous system, and in a too strong form injures the digestive organs." The foregoing remarks, quoted from Harrington's "Practical Hygiene," apply to adults rather than to growing children and youths; for in early life stimulants of every kind should be avoided as much as possible, as they tend to interfere with the healthful development of the body. We should remember that tea and coffee are not foods, and so cannot be of use in repair or growth of tissue, both of which functions are of prime importance during the first twenty years of life. The habitual use of these beverages, especially at breakfast, is also likely to decrease the desire for the food that is needed.

82. Chocolate, cocoa, and soda water. — While it is true that cocoa and chocolate both contain a considerable amount of nutriment when eaten in solid form, when prepared as a beverage, the small amount so used makes its food value relatively unimportant unless milk is used. Chocolate and cocoa contain a certain amount of a stimulant similar to that found in tea and coffee. Since the sirups and ice cream used in the preparation of soda water contain a considerable amount of sugar, these drinks should not be taken habitually between meals, because they tend to impair digestion and to lessen the appetite at meal time (75).

83. Alcoholic beverages. — "In the case of an alcoholic beverage we have to deal with something which, like tea and coffee and cocoa and 'temperance drinks' is used as a beverage, and to that extent must be classed in the same group. Alcoholic drinks are, however, taken as stimulants, and so resemble tea and coffee and cocoa; but they differ from all these in their action upon the body. Moreover, their abuse gives rise not only to degraded moral and social

conditions, but is also attended with bad hygienic effects. Every one should be informed of their nature and of the dangers attending their use." — HOUGH and SEDGWICK, " The Human Mechanism."

84. Alcohol as a possible food. — Like the carbohydrates and fat, alcohol is composed of carbon, hydrogen, and oxygen. Since it contains no nitrogen, it has no value in the processes of growth and repair; in other words, it cannot be made into protoplasm. It cannot, therefore, like meat, milk, and eggs answer as a complete food.

Alcohol we know may be burned in lamps for the production of heat, and in engines for the generation of power. Professor Atwater has shown that alcohol also, if used in sufficiently small amounts, may produce within the human body a certain amount of heat and muscular power. Indeed, in some cases of extreme weakness, especially in diseases, alcohol is regarded by some eminent physicians as necessary for saving life, though even for this purpose it is now being used to a less extent in medical practice.

85. Alcohol as a stimulant and a narcotic. — On account of the amount imbibed, however, alcohol, as ordinarily used in beverages, is practically always either a stimulant or a narcotic. In later sections we shall discuss the effects of alcohol on various organs of the body. One fact should, however, be continually emphasized; namely, that even if it should be taken for granted that alcohol, when used by *adults in moderation*, may generate a certain amount of energy, still *this is an exceedingly dangerous compound* to introduce in any form into the diet of a boy or girl. In the first place, it interferes with the healthy growth of protoplasm; and in the second place, the use of liquors in moderation by a great many people, both young and old, is absolutely im-

possible. Men never become drunkards, paupers, and criminals by taking the nutrients, starch, sugar, fat, or protein, nor does the taste for any one kind of food become uncontrollable, as is so often the case with alcohol. "Till he has tried it, no one can be sure whether he can control his appetite or not. When he has ascertained the fact, it is often too late. The child should be taught to avoid alcohol because it is dangerous to him. The only certain safety for the young lies in total abstinence."

86. Effects of small and large quantities of alcohol. — The effects of alcohol on the body depend very largely upon the quantity taken; if the amount is small, alcohol may possibly be regarded as a source of energy, and hence in a limited sense, as a food; in larger amounts it increases temporarily the activity of the organs of the body, and so it seems to become a stimulant; if still larger quantities are taken, the narcotic effects of alcohol are shown in complete insensibility; and finally, a sufficient amount may be consumed to poison the organs and cause death. No one who begins the use of alcohol expects to take such an amount that it will act as a poison, or even like a narcotic. There is, however, a constant danger that he will do so.

87. Professor Hodge's experiments with dogs. — During the years 1895 to 1900, Professor Hodge of Clark University, Worcester, Mass., carried on some very instructive experiments upon dogs. He secured four spaniel puppies (Fig. 23), all of which were born on Washington's Birthday, 1895; the two males were brothers, and the females sisters. Professor Hodge carefully watched the four for nearly two months before beginning his experiments, in order to pick out the two most vigorous animals; these he named "Tipsy" and "Bum," and then put in with their chief meal each day

a moderate amount of alcohol; it was not enough, however, to cause any evidence of intoxication. The other two spaniels, "Nig" and "Topsy," received no alcohol.

88. Effect of a moderate amount of alcohol on activity. — For over five years these dogs were studied, and important

FIG. 23. — The appearance of the four spaniels six months after the experiments were begun. ("Physiological Aspects of the Liquor Problem," by permission of Dr. Hodge and of Houghton, Mifflin & Co.)

facts were learned as to the general effect of alcohol on physiological processes. Early in his observations it became evident to Professor Hodge that the dogs that were receiving the alcohol were far less playful than were those that had no alcohol in their food. To measure the comparative activity of the different animals, he attached to the collar of each dog a Waterbury watch adjusted in such a way that it would tick

once each time the animal moved, and so at the close of each day he could determine and set down the record made by each dog. He found that for a period of two months and more "Bum" was only 71 per cent as active as "Nig," while "Tipsy" was only 57 per cent as active as "Topsy"; in other words, the two alcoholic dogs lost 25 per cent to 50 per cent of their activity.

89. Effect of a moderate amount of alcohol on skill and endurance. — A second series of experiments was made to determine the comparative endurance of the four dogs and their ability to accomplish things. The animals were all taught to retrieve a rubber ball when it was thrown the length of the gymnasium floor, a distance of 100 feet. At each trial the ball was thrown 100 times, and a record was kept of all the dogs that started for the ball and of the one that succeeded in bringing it back. When he had averaged a long series of experiments, Dr. Hodge found that "Bum" and "Tipsy" secured the ball only about half as often as did "Nig" and "Topsy"; the two alcoholic dogs also gave evidence of much greater fatigue during the trials.

90. Effect of a moderate amount of alcohol in producing nervousness. — "A very striking result of the entire research," says Dr. Hodge, "and one entirely unexpected on account of the small doses of alcohol given, has been the extreme timidity of the alcoholic dogs. . . . While able to hold their own with the other dogs in the kennel, the least thing out of the ordinary caused practically all the alcoholic dogs to exhibit fear, while the others evinced only curiosity or interest. Whistles and bells, in the distance, never ceased to throw them into a panic in which they howled and yelped, while the normal dogs simply barked. This holds true of all the dogs that had alcohol in any amount."

91. Effect of a moderate amount of alcohol on the offspring. — Another most striking result of the use of alcohol was shown in its effects on the young of "Bum" and "Tipsy." Of the twenty-three puppies descended from these alcoholic animals, only 17 per cent lived to be normal dogs; the rest were either deformed or unable to nourish themselves, and all died soon after birth. On the other hand, of the forty-five young of "Nig" and "Topsy," over 90 per cent were healthy puppies. Hence, the puppies of the dogs that took alcohol even in moderation were over *five times* as likely to die young as were the puppies born of abstaining parents.

92. Effect of a moderate amount of alcohol on resistance to disease. — In the spring of 1897, in the course of these experiments, a great many dogs throughout the city of Worcester were afflicted with distemper, and dogs sick with the disease were not uncommon on the streets. At that time, Dr. Hodge had, in all, five dogs that were taking alcohol and four that were not. It was found that there was a marked difference in the effect of the disease on the two classes of animals. All the alcoholic dogs, with the exception of the one that had taken the smallest amount, had the distemper with great severity; all the normal dogs had it in the mildest possible form.

93. Summary of Professor Hodge's conclusions. — Hence, we may conclude from these experiments that alcohol, when given to dogs, even in moderation, (1) decreases their natural activity, (2) lessens their power of endurance and their ability to accomplish things, (3) decreases their power of resistance to disease, and (4) increases the percentage of deformity and of death among their offspring. These conclusions have a most important bearing on the general subject that we are considering, for observations show that sim-

ilar effects follow even the moderate use of liquor by human beings, as the following paragraphs will show.

94. Effect of the moderate use of alcohol on mental activity. — "Few causes are more effective in leading to the abuse of alcohol than the idea that when one finds difficulty in doing a thing it may be accomplished more easily by having recourse to beer, or wine, or whisky for their 'stimulating' effect. In general, so far is this from being the truth that the person seeking such aid is really using a hypnotic and a depressant. Obviously he would be acting more wisely to adopt other methods of accomplishing his end. Nor is this conclusion merely theoretical. Brain workers who wish to "keep a clear head" almost universally avoid alcoholic drinks, at least until work is over. And even among those who do drink it is customary to avoid drinking until the day's work is done."[1]

95. Effect of a moderate use of alcohol on muscular activity. — That the general effect of alcoholic drinks on muscular activity is a depressant rather than a stimulant was shown by experiments on English soldiers during forced marches in Africa. "It was found that when a ration of rum was served out, the soldier at first marched more briskly, but after about three miles had been traversed the effect of it seemed to be worn off, and then he lagged more than before. If a second ration were given, its effect was less marked, and wore off sooner than that of the first. A ration of beef tea, however, seemed to have as great a stimulating effect as one of rum, and not to be followed by any secondary depression." — T. LAUDER-BRUNTON.

96. Effect of a moderate use of alcohol on manual dexterity. — A German scientist determined the effect of alcohol

[1] Hough and Sedgwick, "The Human Mechanism."

on four typesetters in the following way. "Four days were used for the tests, the first and third of which were 'normal' days; the second and fourth were 'alcohol days.' On the alcohol days each man received about seven ounces of a Greek wine . . . a quarter of an hour before the trials took place." On the "alcohol days" it was found that the amount of type set was on the average 15 per cent less than that set on the "normal days."

97. Moderate use of alcohol in relation to disease. — "A much larger number of the victims of alcoholic intemperance die of some infectious disease than of the special alcoholic infections. Attention has been repeatedly called in this article to the lowering of the resistance of alcoholic patients to many infectious diseases. . . . This lowered resistance is manifested both by increased liability to contract the disease and by the greater severity of the disease." — DR. WELCH, in "Physiological Aspects of the Liquor Problem." Physicians also recognize that those who use alcohol are more susceptible to pneumonia, cholera, and other diseases, and that the percentage of recovery of such patients is lower than is that of total abstainers.

98. Total abstinence and life insurance.[1] — "It is now becoming generally recognized that the alcohol habit is one of the main factors in determining length of life. No life office will knowingly accept the proposal of any one known as a hard drinker. Evidence of a very striking kind is rapidly accumulating, which shows that even the moderate use of alcohol is prejudicial to health and longevity. In England about a dozen life offices recognize this fact in one of two

[1] These quotations were furnished the authors by the Equitable Life Assurance Society of the United States.

ways: (1) by giving a reduction of premium to abstainers, or (2) by awarding them a larger share in the profits.

"Ten years ago the American Temperance Life Insurance Association was formed in this city (N. Y.), and accepts nothing but total abstinence risks. It has had pronounced success, and has paid something like $200,000 in death claims. President Frank Delano states that *the results of their business show that the ratio of their death rate to that of general risks is about* 26 *per cent in favor of the total abstainer.*" — William E. Johnson.

99. Business arguments for total abstinence. — The value of total abstinence as a business asset is clearly shown by the following rules of railroads: Rule 17, New York Central & Hudson River R.R.: "The use of intoxicating drink on the road or about the premises of the corporation is strictly forbidden. No one will be employed, or continued in employment, who is known to be in the habit of drinking intoxicating liquor."

Rule H, New York, New Haven & Hartford R.R.: "The use of intoxicants by employees while on duty is prohibited. Their habitual use, or the frequenting of places where they are sold, is sufficient cause for dismissal."

General Order No. 12, Delaware, Lackawanna & Western R.R.: "The use of intoxicants while on or off duty, or the visiting of saloons or places where liquor is sold, incapacitates men for railroad service, and is absolutely prohibited. Any violation of this rule by employees in engine, train, yard, or station service will be sufficient cause for dismissal."

100. The cost of intemperance. — The following figures, compiled by the League for Social Service of New York City from the United States Census, present some very striking

facts as to the cost to our country of the abuse of alcohol. During the year 1880 (and the same figures would doubtless hold true for any other year), it was found that *three fourths* of all the pauperism, *one fourth* of all the insanity, and *three fourths* of all the crime in the United States were directly caused by intoxicating drinks. Hence if the use of intoxicating liquor could be abolished, the heavy expense of maintaining the police force, the criminal courts, insane asylums, and charity organizations, would be very greatly reduced.

101. Concluding remarks on the use of alcoholic beverages. — "In the foregoing pages we have stated the salient facts concerning the physiological action of alcohol and alcoholic drinks. It only remains to point out for the student the obvious conclusions to be drawn from them and from the long and on the whole very sad experience of the race with alcoholic drinks. The first is that, except in sickness and under the advice of a physician, alcoholic drinks are wholly unnecessary, and much more likely to prove harmful than beneficial. The last is that their frequent, and especially their constant, use is attended with the gravest danger to the user, no matter how strong or self-controlled he may be. . . . The only absolutely safe attitude toward alcoholic drinks is that of total abstinence from their use as beverages." — Hough and Sedgwick, "The Human Mechanism."

III. Tobacco

102. Effect of tobacco on growth. — In discussing the effects of tobacco, it is important, as was the case with tea and coffee, to distinguish between the results of its use by the young and by adults. Just because his father seems to be using tobacco without harm is no reason why a boy can safely smoke. We have already called attention to the complex

composition of protoplasm. During the whole period in which the body is attaining its growth this living substance is affected far more appreciably and seriously by the use of stimulants and narcotics than is the case later in life.

Tobacco is a narcotic in its effects; that is, it tends to decrease activity and likewise growth. That such is its effect during early life has been abundantly proved in many ways. But perhaps the most conclusive facts are those presented by actual measurements made in college gymnasiums. Dr. Hitchcock, of Amherst College, who has made careful measurements of college students for a good many years, finds that those who do not smoke increase in height during their college course 37 per cent more than those who do smoke, and in chest girth this difference is 42 per cent, or nearly one half as much again. Dr. Seaver of the Yale Gymnasium finds, also, that in height and lung capacity smokers are considerably inferior to those who do not use tobacco.

103. Effect of tobacco on mental development. — Dr. George L. Meylan, Director of the gymnasium of Columbia University, made a careful comparison during two years of the relative physical measurements, rate of growth, and scholarship of 115 college men who smoked and 108 men in the same class who were non-smokers.[1] He found (1) that the smokers were on the average eight months older, which means that they had entered college this much later; and (2) that "the scholarship standing of smokers was distinctly lower than that of the non-smokers," showing "that the use of tobacco by college students is closely associated with idleness, lack of ambition, lack of application, and low scholarship."

[1] *Popular Science Monthly*, August, 1910.

"Whatever difference of opinion there may be regarding the effect of tobacco on adults — and much difference of opinion exists — there is almost complete agreement among those best qualified to know that the use of tobacco is in a high degree harmful to children and youths. Physicians, teachers, and others who have much to do with boys very generally remark that those who begin to smoke at an early age very seldom amount to much."

Dr. Andrew D. White, for twenty years President of Cornell University, out of his wide experience in education, sums up the matter as follows: "I never knew a student to smoke cigarettes who did not disappoint expectations, or to use a vernacular expression, 'kinder peter out.' I consider a student in college who smokes as actually handicapping himself for his whole future career. I am not fanatical in regard to smoking. It seems to me possible that men who have attained their growth and are in full health and strength may not be injured by moderate smoking at times. I will confess to you that at one period of my life I was a smoker myself, though in a very moderate degree. And should you feel a strong desire to smoke, thinking it may rest you and change happily at times the current of your thought, I may perhaps commend to you my own example; for I began my smoking at the age of forty-five and ended it ten years ago at the age of seventy."

104. Tobacco and athletics. — One of the rules rigidly enforced in athletic contests is that all candidates must abstain from the use of tobacco while in training. The reason for this insistence is the fact that tobacco seriously interferes with the action of the lungs and heart; therefore, those who smoke are found to be easily "winded" in the games.

An investigation[1] has been recently carried on among the football squads of fourteen of the American colleges and universities to determine the relative success of the smokers and non-smokers who tried for positions on the varsity teams.

"Six institutions furnished data relating to the 'try outs.' A total of 210 men contested for positions on the first teams; of this number 93 were smokers, and 117 were non-smokers. Of those who were successful, 31 (*i.e.* 33 %) were smokers, and 77 (*i.e.* 65 %) were non-smokers. It will be observed that only half as many smokers were successful as non-smokers. . . ."

Hence, the ambitious boy, who has any regard for developing a vigorous body fitted for athletic success, for training a mind capable of clear thinking, and for preparing himself for a successful life work, will resist all temptations to smoke, at least until he has attained his full growth.

IV. Drugs and Patent Medicines

105. Headache powders. — Drugs are chemical substances used in the preparation of medicines. They should never be taken except under the direction of a competent physician. Headache medicines usually contain some chemical (*e.g.* acetanilid) which reduces the heart action and so relieves the pain by diminishing the blood pressure without removing the cause of the pain; for the real cause may be disordered digestion or eye strain. Cases of permanent injury and even of death have resulted from taking these headache compounds (Fig. 24).

106. Soothing sirups and cough medicines. — In most soothing sirups and cough medicines are found substances derived from opium, which is a powerful narcotic. Hence,

[1] "Smoking and Football Men." — *Popular Science Monthly*, October, 1912.

children who are given soothing sirups often become stupefied. If these compounds are given frequently, they injure the child permanently, and in larger doses have caused death. If cough sirups and like compounds are taken often, an opium

BEWARE OF ACETANILID

A large proportion of the most common headache medicines sold at drug stores depend for their effectiveness on the heart-depressing action of acetanilid. In some cases three or more grains of this drug are present in each dose.

The Pure Food and Drug Law requires all makers of patent medicines to indicate clearly on the labels of such preparations the presence of acetanilid and other dangerous compounds. Hence one has but to read the labels and avoid these nostrums in order to protect himself.

Take no headache remedy without consulting a doctor, unless you are sure it contains no acetanilid. Make the druggist tell you. He is responsible. A suit for damages has recently been won against a New York drug store for illness consequent upon the sale of a "guaranteed harmless" headache tablet containing three grains of acetanilid.

Fig. 24. — Acetanilid and other drugs in patent medicines.

habit may be developed, which is even more difficult to overcome than is the alcohol habit.

107. Patent medicines as "bracers." — Figure 25 represents the percentage of alcohol contained in three "patent medicines" as given by the Massachusetts State Board of

FIG. 25. — Percentage of alcohol in patent medicines and in liquors.

Health in published document No. 34, as compared with the percentages of alcohol found in whisky, champagne, claret, and beer. The stomach bitters (Fig. 25), for example, contained over eight times as much alcohol as that found in beer. Hence, the average drug store where these patent medicines are freely sold must share with the liquor saloon the heavy responsibility for the prevalence of the drink habit.

108. Pure food and drug law. — One of the most important laws passed by the 59th Congress of the United States was that which compels every manufacturer of foods or medicines to state on the label the composition of each. Analyses of foods and drugs have proved that hitherto many of them were largely adulterated by cheap and often injurious compounds, put in to increase the manufacturers' profits. Then, too, as already stated, many patent medicines contain high percentages of alcohol and other dangerous drugs. Under the new law the purchaser, if he takes the trouble to read the printed label, should be able to determine exactly what he is paying for and putting into his body.

109. Optional home work. — Examine the labels on any patent medicine bottles or boxes you can find. Make a list of such compounds as contain alcohol, opium, morphine, chloral, acetanilid, or phenacetin, and state after each compound the percentage of each of the drugs named.

CHAPTER V

DIGESTION AND ABSORPTION OF THE NUTRIENTS

I. General Survey of the Digestive System

110. Necessity of digestion. — In Chapter III we discussed the composition, uses, and the preparation of foods. We learned in our study of plant biology (**P. B.**, Ch. IV) that certain of the food substances will readily pass through the walls of plant cells, while others will not. Hence, the latter, to become available for use in other cells, must be changed to soluble form, and this change we called *digestion.* We shall now discuss similar changes that take place in foods within our bodies; for before the different food substances can reach the cells of the brain, the muscles, or the bones where they are needed, they must be changed from a solid or semifluid condition into liquids that can pass through the walls of the cells that lie between the interior of the food canal and the blood. These necessary changes are accomplished within our bodies in the *alimentary canal,* a complicated tube nearly thirty feet in length.

111. Parts of the alimentary canal. — The alimentary canal (Fig. 26), as in the other vertebrates studied, begins with the *mouth opening;* it enlarges to form the *mouth cavity,* and this in turn communicates behind with a somewhat smaller *throat cavity.* Below the throat is the *gullet,* which conducts the food into an enlarged pouch, the *stomach.* Most of the lower half of the trunk is filled with the much coiled

intestines which begin at the stomach and open to the outside of the body at the lower part of the trunk.

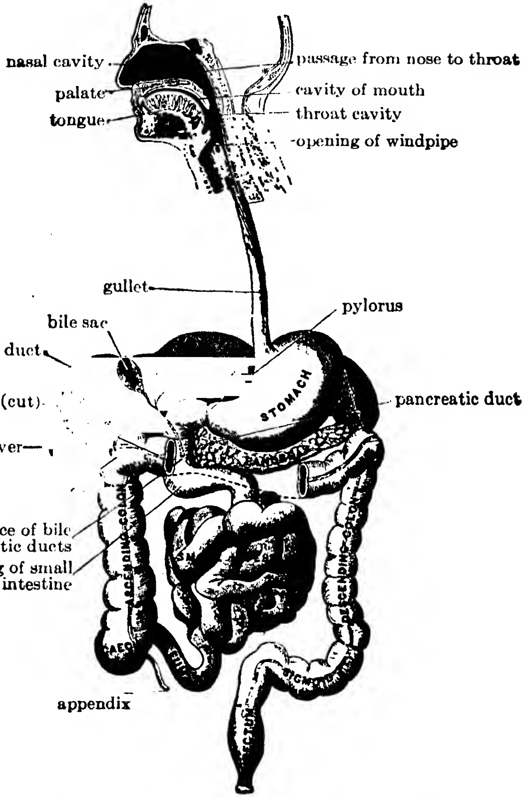


FIG. 26. — Parts of the alimentary canal. (The liver has been tilted upward to show the gall bladder on its lower surface; a piece of the large intestine has been removed to show the pancreas behind it.) Compare this figure with Fig. 2 which shows all the organs in position.

112. Digestive glands. — Several organs that are necessary in the process of digestion, as already discussed in the

fish and frog, lie outside the alimentary canal itself, but are connected with it. These are the *digestive glands.* They produce *digestive ferments* (**P. B., 53**), which after being dissolved in water are carried into the food canal through small pipes or *ducts.* Thus the *salivary glands* pour their secretions into the mouth cavity, and the *liver* and *pancreas,* situated near the stomach, empty their juices into the intestine (Fig. 26).

II. The Mouth Cavity and its Functions

113. Study of the mouth cavity. — (Home work.)

Take a position with your back toward a window or some bright light, and study your mouth cavity by means of a hand mirror.

A. Walls of the mouth cavity. — The walls that are rigid are composed largely of bone; those that are yielding are largely made of muscle.

1. Press your forefinger against the roof, the side walls, and the floor of the mouth cavity beneath the tongue Which walls are composed of bone? which of muscle?
2. What is the color of the inner walls of the mouth cavity? This color is due to the blood vessels that lie close to the surface.
3. Rub your finger over the *mucous membrane* which covers these walls. The substance on your finger is largely *mucus.* Describe the mucus and tell where it is found.

B. Tongue.

1. To what part of the mouth cavity is the tongue attached?
2. Chew a piece of apple or other solid food; note and describe the action of the tongue during the process of chewing food.
3. Swallow some solid food, and describe the action of the tongue in the process of swallowing.

114. Structure and functions of the tongue. — The tongue is an elongated mass of muscle tissue (Fig. 27). The muscle fibers run through it in three directions, and by their separate or combined action the free end of this organ may be moved about at will. When one examines the mucous membrane on the upper surface of the tongue, it is possible to see elevations of different sizes, called *papillæ*. Nerve fibers carry messages from these papillæ to the brain, and thus we become conscious of sensations of taste. Among the *carnivora* or flesh-eating animals the papillæ on the tongue are especially rigid. This enables the dog, cat, lion, or tiger to scrape the meat from the bones and to extract the marrow after the bones are broken open.

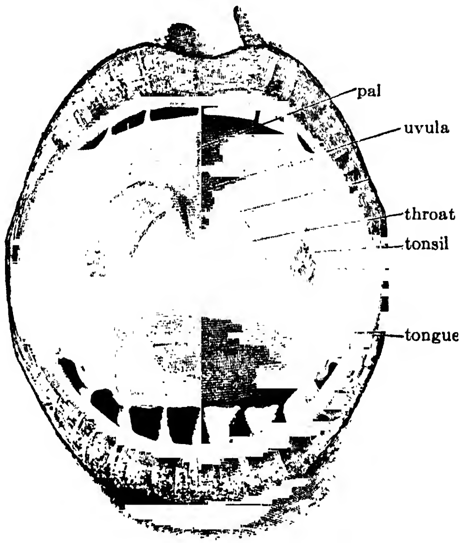


Fig. 27. — Mouth cavity.

115. Study of the teeth. — (Home work.)

1. Bite off a piece of apple or bread.
   a. Describe the motion of the lower jaw in biting off a piece of food.
   b. In what part of each jaw are found the teeth that are used in biting food?
   c. Describe the shape and cutting surface of these teeth.

2. Chew or grind a piece of apple or bread.
   a. Describe the motion of the jaw in grinding food.
   b. In what part of each jaw are found the teeth that are used in grinding or chewing food (Fig. 28)?
   c. Describe the shape and grinding surface of these teeth.
3. There are two kinds of cutting or biting teeth (Fig. 28), the *incisors* (Latin, *incisum*, from *incidere* = to cut into), and the *canines* (Latin, *canis* = dog, so-called because they often resemble the pointed teeth of a dog).

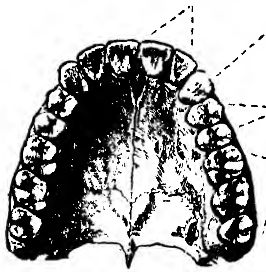


FIG. 28.—Teeth in upper jaw.

There are also two kinds of grinding teeth, the *bicuspids* (Latin, *bi* = two + *cuspis* = point), and the *molars* (Latin, *molaris* = a millstone).

   a. (Optional.) Human teeth may be obtained from a dentist. They should be cleaned by boiling them in strong caustic soda solution, then in water. If possible, each student should examine and draw one of each of the kinds of teeth named above.
   b. Determine by the use of a mirror the number of teeth of each kind that you have and record the numbers in a table in your notebook as follows: —

	RIGHT HALF OF UPPER JAW	LEFT HALF OF UPPER JAW	RIGHT HALF OF LOWER JAW	LEFT HALF OF LOWER JAW
Incisors. . .				
Canines . .				
Bicuspids . .				
Molars . . .				

4. Examine carefully each of the teeth in your mouth and indicate in a table like the following the number of cavities (unfilled) and the number of fillings that you find.

	Right Half of Upper Jaw		Left Half of Upper Jaw		Right Half of Lower Jaw		Left Half of Lower Jaw	
	Cavity	Filling	Cavity	Filling	Cavity	Filling	Cavity	Filling
Incisors . .								
Canines . .								
Bicuspids .								
Molars . .								

116. Arrangement of the teeth. — Within the mouth cavity the solid food is cut into small pieces, mixed with the juices of the mouth, and then ground into a pulpy mass. A large part of this work is done by the teeth, which are arranged in two semicircular arches (Fig. 29). In a normal set of teeth each tooth in the lower jaw works against a corresponding tooth in the upper jaw, and this is very necessary in order to chew the food properly and to keep teeth and gums in a healthy condition. If, however, the teeth do not develop as described above, a competent dentist should be employed to correct the irregularities.

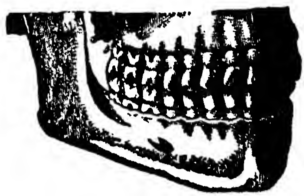


Fig. 29. — Arrangement of the teeth.

117. Milk teeth. — During early childhood there appears a first set of *milk teeth,* which later are gradually loosened and dis-

placed by the growth of the *permanent set.* There are but twenty teeth in the milk set and their arrangement is as follows: —

	Right Half of Upper Jaw	Left Half of Upper Jaw	Right Half of Lower Jaw	Left Half of Lower Jaw
Incisors . . .	2	2	2	2
Canines . . .	1	1	1	1
Molars . . .	2	2	2	2

Bicuspids are, therefore, wanting, and the milk molars occupy the position in each half jaw that later is filled by the two bicuspids of the permanent set. The teeth appear gradually, the lower incisors usually being the first to push through the gums at about the sixth month. The third permanent molars of each half jaw often appear as late as the twentieth year; they are called the *wisdom teeth.*

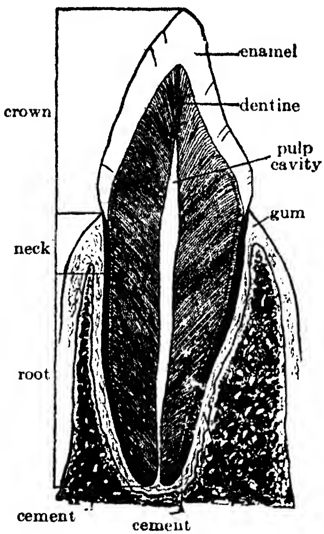


Fig. 30. — Longitudinal section of a canine tooth.

118. Structure of teeth. — The exposed portion of a tooth is called the *crown* (Fig. 30). It is covered with a layer of *enamel,* which is the hardest tissue in the body. The *root* of the tooth is imbedded in a socket in the bone of the jaw. It has no enamel, but, instead, its outer layer is a modified bone tissue called *cement.* The incisors and canines usually have but a single root, the bicuspids may have two, and the molars are often held in the jawbone by three, four, or five roots. In the region be-

tween the crown and the root is the *neck* of the tooth, which is surrounded by the gums.

The internal structure of the tooth is well shown in a vertical section (Fig. 30). The covering of enamel is thickest over the top of the crown; it becomes thinner down the exposed sides, and disappears in the neck region. The largest part of the tooth is composed of bony *dentine*. In the central part is the *pulp cavity*. This region is well supplied with nerves and blood vessels, which enter through a small opening at the end of each root. The blood furnishes the teeth with new building material.

119. Care of the teeth. — Too much stress cannot be laid on the importance of caring for the teeth, since decaying teeth are frequently painful, are always unsightly, are usually the cause of an ill-smelling breath, and often lead to indigestion. Immediately after eating, one should remove any bits of food from between the teeth by using a wooden toothpick, dental floss, or thread. Pins, knife-blades, or other metallic implements should never be used for this purpose. The teeth should then be brushed thoroughly on all sides, and warm water and a little castile soap or reliable tooth powder should be used. The sides of the teeth should be brushed from the gums toward the crown in order to avoid pushing the gums away from the neck of the tooth.

Since the enamel that covers the crown of the tooth is composed entirely of mineral matter, it cannot, of course, decay. If, however, food is allowed to decompose on or between the teeth, the acids formed by the action of the bacteria gradually dissolve the enamel until a cavity is formed. When the dentine is reached, the bacteria directly cause this part of the tooth to decay, since it contains living matter.

The teeth ought never to be used to crack nuts or to bite hard substances, for while the enamel is a very hard substance, it is also brittle and may be cracked or broken off by such treatment. If once lost, it will not grow again. It is evident, therefore, that it is very essential to protect this outer layer, both from the action of acids, and from mechanical injuries.

Some people seem to think that the loss of natural teeth is not a very serious matter, and that false teeth are just as effective as those teeth provided by nature. Experiments have shown, however, that the power to crush food with false teeth is only about one fifth that of the power exerted by a normal set of teeth. Hence, loss of teeth is very likely to result in imperfect mastication of food, with consequent ill-health resulting from indigestion. If, however, one has been unfortunate enough to have lost one or more teeth, the gaps should be promptly filled by bridge work. The teeth should be examined by a dentist at least *twice a year* so that any cavities found may be promptly filled. In short, *everything possible should be done to secure and preserve a beautiful and effective set of teeth.*

120. Importance of the digestion of starch. — In **47** of "Plant Biology" we proved that starch can not pass through the walls of cells, and we likewise showed in **49** how this food substance is made ready by the process of digestion to pass through membranes. Many of the foods we eat contain large percentages of starch. We are now to show experimentally how starch is digested in the human body.

121. Does saliva digest starch? — Laboratory demonstration.

Prepare some starch paste by boiling in a test tube of water an amount of arrowroot starch (or corn starch, if

the arrowroot cannot be obtained) equal to half the size of a pea.

1. Pour a small amount of the starch paste into a test tube, add some Fehling's solution, and boil. Is grape sugar present? How do you know?
2. Put some saliva into a clean test tube. Test it with Fehling's solution as you did the starch. Does this saliva contain grape sugar? How do you know?
3. In another clean test tube pour some saliva into some of the starch paste, shake the mixture, and warm it gently for a few moments to the same temperature as that of the mouth. Now test with Fehling's solution, as in 1 above.
   a. State what was done, the result, and the conclusion.
   b. What, therefore, is the effect of saliva on boiled starch?
   c. Name several foods already studied that could be partially digested by saliva.

4. (Optional home work.) Take some popped corn or shredded wheat into the mouth and chew it thoroughly. Can you detect any sweet taste at first? Can you after chewing for a time? What does this experiment teach you as to one advantage of thoroughly chewing the food?

122. Position and action of the salivary glands. — In addition to the mucus given out by the mucous membrane (**113**) the mouth receives another secretion called *saliva.* At the sight or smell of tempting food "the mouth waters." Saliva is secreted by the *salivary glands.* Two of these glands (the *parotids,* from Greek, meaning "beside the ear") are located near the back of the lower jawbone just beneath and in front of the ear. Any one who has had the mumps can readily locate these organs, for mumps is a disease in which these glands swell. From the parotid gland of each side a duct conveys saliva along through the walls of the cheek. This duct opens at the top of a small elevation, which may be felt with the tip of one's tongue opposite the upper second molar teeth.

Two other pairs of glands (the *submaxillary,* Latin, *sub* = beneath + *maxilla* = jawbone, and the *sublingual,* Latin, *sub* =

beneath + *lingua* = tongue) lie in the muscular floor of the mouth cavity, and the ducts from these glands open in the floor of the mouth under the tongue.

123. Uses of saliva. — (1) The saliva aids the mucus in keeping the mouth moist, and thus we are enabled to talk easily. (2) It moistens the food for swallowing. The importance of this function is appreciated when one tries to hurry in swallowing the crumbs of dry cracker. (3) Saliva helps to dissolve sugar and salt,[1] thus enabling us to taste them. If the tongue is wiped dry and a piece of sugar is placed upon it, we have no sensation of taste until the sugar has been partially dissolved by the mixture of saliva and mucus that is poured upon it. (4) Besides the three mechanical functions of saliva that we have just enumerated, this secretion digests cooked starch, as we have already shown. This digestive action is due to a ferment known as *ptyalin* (pronounced ty′alin) which acts in the same manner as the diastase found in plants.

III. The Throat Cavity and Gullet and their Functions

124. Structure of the throat and gullet. — The cavity of the throat is behind the mouth. If one holds a mirror in front of the mouth opening and presses down upon the tongue with a spoon, one sees hanging down a small, fingerlike extension of the soft palate, called the *uvula*. When food is swallowed, this little tongue of the soft palate is shoved backward into a horizontal position, where it helps to separate the throat cavity from the nose cavity.

The lower part of the throat narrows into the *gullet*. This tube traverses the length of the chest cavity, and as it nears the stomach, it passes through the diaphragm. Like all other parts of the alimentary canal it is lined with mucous membrane, which furnishes a

[1] See **130**, *A*, 1.

soft, moist surface for the passage of food. Outside the mucous membrane are rings of circular muscle running around the gullet.

125. Functions of the throat and gullet. — The food is quickly forced out of the throat cavity into the gullet, and is pushed slowly down the gullet by the successive contractions of the rings of muscle just described. After being swallowed from the throat, the food does not drop into the stomach, for the walls of the gullet are pressed together by surrounding organs, except when this tube is opened by the passing food. In fact, after practice, one can swallow when standing on one's head, and most quadrupeds (horse, dog, cow), when feeding, hold the head below the level of the stomach.

IV. The Stomach and its Functions

126. Position, size, shape. — The stomach is a curved muscular pouch, which lies about midway between the upper and lower ends of the trunk, with its larger end lying toward the left side of the body, where it communicates with the gullet (Fig. 26). When moderately filled, this organ holds about three pints. The small intestine is continuous with the right end of the stomach, the communication between the two (known as the *pylorus*, from Greek, meaning gatekeeper) being controlled by a ring of muscle.

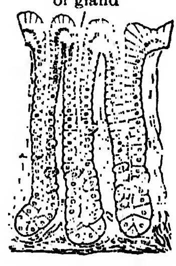


Fig. 31. — Three gastric glands.

127. The lining of the stomach and the gastric glands. — If one examines with a lens the mucous lining of the stomach, a countless number of small openings are seen which look like pin pricks. These are the pores through which a digestive fluid known as *gastric juice* is discharged from the *gastric glands* (Fig. 31). This digestive fluid is composed of water

(over 99 per cent), free *hydrochloric* acid and a digestive ferment called *pepsin*.

128. Muscles of the stomach. — The chief function of the human stomach is to secrete the gastric juice and to mix this juice thoroughly with the food. The muscular walls are well adapted for this purpose. When the food reaches the stomach, the gastric juice oozes out upon it, and the mixture is pushed back and forth and up and down by the successive action of the different layers of muscles. The return of the food to the mouth cavity is prevented by the contraction of the circular muscles at the lower end of the gullet, except in the case of nausea, when they relax and allow the stomach to rid itself of its contents. The circular muscle at the pyloric end of the stomach (Fig. 26) relaxes from time to time, and the partially digested food is pushed on into the intestine.

Fortunately for the well-being of the body, all these processes are entirely automatic; that is, they are carried on without our conscious direction. The muscles of the alimentary canal for this reason are called *involuntary* (Latin, *in* = without + *voluntas* = will).

129. Digestion in the stomach. — The gastric juice has practically no effect on the nutrients starch and fat. The saliva, however, that is mixed with the food and swallowed with it continues to act upon the starch for a time, particularly in the upper part of the stomach. Sugars and soluble salts (that is, salts that dissolve in water), if not dissolved in the mouth, are readily liquefied by the water of the gastric juice. Certain mineral food substances, however, like phosphate of lime found in milk, are not soluble in water, and these *insoluble salts* reach the stomach unchanged. The following experiment illustrates the way in which mineral matters are made liquid by the hydrochloric acid in the gastric juice.

130. Digestion of mineral matters. — (Optional.) Laboratory demonstration.

Note to Teacher: Part A should be demonstrated in connection with the study of saliva; Part B, in connection with gastric digestion.

Materials: Table salt, phosphate of lime, diluted hydrochloric acid (one part acid to six parts water).

A. Soluble mineral matters.

1. Put some table salt into a test tube, add water, and shake well. Does the salt dissolve? How do you know?
2. Saliva is largely (over 99 per cent) composed of water. How, then, are soluble mineral matters made liquid in the mouth?

B. Insoluble mineral matters.

1. Put some insoluble mineral matter like phosphate of lime (which is one of the constituents of milk) into a test tube, add water, and shake well, then allow the tube to stand for a time before answering the following questions.
   a. Does phosphate of lime dissolve in water? How do you know? Why is phosphate of lime called an insoluble mineral matter?
   b. Shake the mixture again and add some diluted hydrochloric acid. What change do you observe?
2. Hydrochloric acid is one of the ingredients of gastric juice. How, then, are insoluble mineral matters like phosphate of lime digested in the stomach?

131. Digestion of proteins. — One of the most important actions which takes place in the stomach is the digestion of proteins. This class of nutrients is not readily soluble in water and so cannot pass through the walls of cells (**P. B., 52**). Hence, before proteins can be made available for use in the body they must be changed to a soluble form known as

peptone (**P. B.**, **53**). This chemical change is brought about in our bodies to some extent by the gastric juice.

132. Digestion of proteins. — Optional laboratory demonstration.

Materials: Boiled egg, powdered pepsin (which should be obtained fresh or kept in a tightly stoppered bottle), hydrochloric acid, water; test tubes. Each of the following experiments should be kept throughout the whole time as nearly as possible at the temperature of the body (98.6° F.).

A. *To prove that protein requires digestion after it is swallowed.*

1. Shave off with a knife and cut into the finest pieces possible a part of the white of a boiled egg (or better, grate the egg). The solid constituents of egg are largely protein. Put into a test tube a small amount (about twice the size of a pea) of this minced egg, add water, and shake. Label the test tube No. 1, and allow the mixture to stand for a day or two as nearly as possible at a temperature of 98.6° F. (which is the normal temperature of the interior of our bodies).
   - *a.* Has *all* the egg been made liquid or digested by the water? How do you know?
   - *b.* Pour off some of the clear liquid into a test tube, and add nitric acid and boil. Has *any* of the protein been digested? How do you know?
2. Into another test tube put the same amount of minced egg, add a spoonful or more of saliva. Label it test tube No. 2. Shake and allow it to stand for a day or two beside test tube No. 1.
   - *a.* Is protein digested by saliva? How do you know?
   - *b.* What do you therefore conclude in regard to the possibility of protein-digestion by the saliva?

B. *To prove that gastric juice digests protein.*

1. Into a third test tube put a small amount of the minced egg. Half fill the tube with water, add powdered pepsin to

the amount equal to about the size of a pea, and also add five to ten drops of diluted hydrochloric acid. (Water, pepsin, and hydrochloric acid are the three principal ingredients of gastric juice.) Label the test tube No. 3, shake the mixture, and put it in a warm place beside test tubes 1 and 2. (Since it is difficult to get the exact proportion of the three ingredients of gastric juice, it is well to prepare several tubes as described above, labelling each test tube No. 3.) At the end of a few hours or a day examine the test tubes containing the minced egg and the artificial gastric juice, comparing them with test tubes 1 and 2. Has the egg been digested? How do you know?

V. The Small Intestine and its Functions

133. Position, form, and size. — The small intestine is a much-coiled tube, filling the larger portion of the abdominal cavity (Fig. 2). It is usually twenty feet or more in length, and therefore constitutes nearly four fifths of the whole length of the alimentary canal. Beginning at the stomach, it decreases somewhat in size until it opens into the large intestine.

134. Peritoneum. — The whole abdominal cavity is lined with thin, smooth membrane called the *peritoneum.* Sheets of peritoneum likewise inclose the various organs found in the abdominal cavity, and help to connect these organs to the walls of the abdomen. *Peritonitis* is an inflammation of any portion of this membrane.

135. Digestion in the small intestines. — In the intestines important digestive processes are carried on (1) by the juices secreted in the glands found in the inner wall of the intestine (*intestinal glands*), (2) by the pancreatic juice secreted by the pancreas, and (3) by the bile secreted by the liver. All these juices, when mixed with the food in the intestine,

bring about the digestion of fats and complete the digestion of starch and proteins.

The pancreas (Fig. 26) lies just below the stomach and extends from the region of the pylorus toward the left side of the body. Within the gland is secreted the pancreatic juice, which is poured out through a duct upon the food just after it enters the small intestine. Pancreatic juice digests three of the nutrients; namely, starch, proteins, and fats. Like saliva, pancreatic juice changes starch into sugar, and like gastric juice, it converts proteins into peptones. The heat of the body melts much of the fat before it reaches the intestine, but this liquid cannot be absorbed until it has been still further acted upon chemically by the pancreatic juice and bile.

VI. The Large Intestine and its Functions

136. Position, form, and size. — The large intestine is the last portion of the alimentary canal. It is a tube five or six feet long, with a gradually decreasing diameter. Beginning in the lower right-hand region of the abdominal cavity as a sac-like pouch (Fig. 26), the large intestine passes upward on the right side of the body cavity to the lower surface of the stomach; it then crosses the abdominal cavity; a third portion continues downward on the left side. The large intestine then takes an S-shaped course and passes to the exterior of the body by a short, straight tube.

137. Vermiform appendix. — On the right side of the body, and connected with the beginning of the large intestine, is a small, tubular sac about the size of a lead pencil, and usually about four inches long (Fig. 26). From its more or less twisted shape it has received the name *vermiform appendix* (Latin, *vermiform* = worm-shaped). *Appendicitis* is a diseased condition arising from inflammation in the tissues of the appendix.

VII. Absorption from the Alimentary Canal

138. Necessity for the absorption of food. — We have now learned something of the processes of digestion. We

have seen that the foods we eat are ground up in the mouth cavity by the teeth and thus made ready for the action of the various digestive juices. We have also demonstrated that sugars and soluble salts are dissolved in the mouth; that insoluble mineral matters are made soluble in the stomach; that starch is changed to sugar by the saliva and pancreatic juice; that proteins are converted into peptones by the pancreatic and gastric juices; and that fats are digested in the intestines by the combined action of bile and pancreatic juice. Were the food to remain within the alimentary canal, however, even though it had been thoroughly digested, it would still be, in a certain sense, outside the body, since this canal is a continuous tube opening to the exterior at either end. In order to furnish material for building and repairing the various tissues, the liquid nutrients must be distributed to the tissues wherever needed. This is accomplished through the agency of the blood system. We have now to consider the process of absorption, which includes the final steps whereby foods become a part of blood. *By absorption is meant the passage of the digested food through the lining of the alimentary canal, and through the thin walls of the countless blood vessels that lie close at hand.*

139. Absorption in the mouth, throat, gullet, and stomach. — While the mouth, throat, and gullet all have a moist lining, generously supplied with thin-walled blood vessels, relatively little absorption takes place in these regions; first, because only a small amount of the food has been digested, and secondly, because the food does not remain long enough in these organs for absorption to take place.

The food usually remains in the stomach for several hours, and one would naturally expect that a good deal of absorption would take place during this time. But we must remember that the contraction of the stomach muscles keeps the food in constant motion

This movement, while favorable to digestion, diminishes absorption, because the liquefied food does not remain long enough in one place to be absorbed by the blood.

140. Absorption in the small intestine. — We, therefore, find that most of our food passes through the pylorus before it is absorbed. In the structure of the small intestine, however, we seem to find every possible provision for gathering up the nutrients. In the first place, the lining of this tube at intervals is elevated to form ridges that run two thirds of the way around the interior wall, and some of them project about a third of an inch into the cavity of the intestines (Fig. 2). Like little dams, they delay the onward flow of the food, and they also increase considerably the large surface for absorption.

The absorbing surface is multiplied still further by the *villi*. If one were to examine with a hand lens the mucous lining of the small intestine, one would see that the ridges and the depressions are covered with tiny, hairlike processes that give a velvety appearance to the surface. Each of these minute elevations is called a *villus* (Latin, *villus* = a tuft of hair). The villi are exceedingly numerous in the small intestine of man, the total number being estimated at four millions. The absorbent action of the villi may be compared with the absorption that takes place through the walls of the root hairs of plants. In structure, however, a villus is much more complicated than is a root hair.

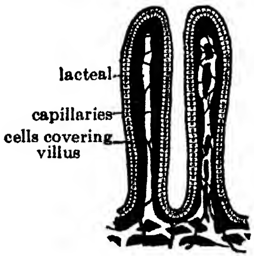


FIG. 32. — Two villi, highly magnified.

Each villus (Fig. 32) when highly magnified, is found to contain a network of minute blood vessels, and since they are covered only by a thin layer of cells on the outside of the

villus, the liquefied food is readily absorbed by the blood current. Within the villi, too, are other thin-walled tubes, called *lacteals*, which are of great importance in the absorption of fats. As the souplike mass of food is pushed slowly along through the small intestine, it becomes less and less in bulk, and more and more solid, owing to the fact that the dissolved salts, sugars, peptones, and fats are largely taken up by the blood vessels and lacteals within the villi.

141. Absorption in the large intestine. — The amount of absorption in the large intestine is considerably less, of course, for both villi and ridges are wanting. Yet even here considerable absorption takes place. When the mass reaches the lower end of the intestine, it consists of little but the indigestible cellulose of vegetable foods, some undigested connective tissue, waste substances from the bile, the solids in the mucous secretion, and some raw starch and undigested fats if large quantities of these nutrients have been eaten. This refuse of the food is thrown off from the body.

VIII. The Liver and its Functions

142. Position, form, size. — The human liver (Fig. 26) is the largest gland of the body, weighing three to four pounds. It lies toward the right side of the body, just beneath the diaphragm, and partially covers the pyloric end of the stomach. It consists of several lobes, and on its under surface there is a small, greenish brown sac called the *gall bladder*. The deep red color of the liver is partly due to the fact that one fourth of all the blood of the body is found within its tissues.

143. Functions of the liver. — The liver performs three important functions. In the first place, it secretes a golden brown liquid called the *bile*, which is either poured at once through the *bile duct* into the small intestine or is stored in the gall bladder until needed. If the bile duct becomes stopped up, the bile is absorbed into the blood and gives to the tissues the yellow tint that is characteristic

of *jaundice.* The liver, in the second place, serves as a great storehouse for the carbohydrates when the blood does not need them for immediate use. When, on the other hand, there is a lack of carbohydrates in the blood, some of the supply in the liver is taken up again by the blood. Finally, the liver helps to destroy some of the worn out cells of the blood (the red corpuscles), and the waste materials thus formed are passed off into the intestine as a part of the bile.

IX. Hygiene of Digestion

144. Hygienic habits of eating. — One should form the habit of eating slowly and of thoroughly masticating each mouthful of food. For by this process the food is thoroughly broken up, and thus is prepared for rapid digestion not only in the stomach but in the intestines as well. The process of chewing likewise stimulates the flow of saliva. Saliva not only helps digest food in the mouth, but this juice also, when swallowed with the food, continues for a time the digestion of starch in the stomach and likewise stimulates to greater activity the glands in the walls of the stomach.

At least a half hour should be devoted to the eating of dinner and twenty minutes to breakfast, lunch, or supper. The proper digestion of food depends in no small degree upon one's mental state; worry and disagreeable topics should, therefore, be forgotten as far as possible while one is eating, and the mealtime should be made a season of enjoyment. Regular hours of eating are of great importance, for nothing more commonly deranges the digestive system than the continual nibbling of food or sweetmeats between meals. One should refrain from vigorous exercise or mental exertion for some time after eating; the reason for this will be clear after a study of the blood system.

145. Prevention of disease. — To insure a state of health the useless residue of the food should be expelled from the

large intestine regularly each day. If this is not done, serious disturbances of the health are sure to follow. By *constipation* is meant the abnormal retention of waste matter in the intestine. "The causes of constipation are imperfect digestion (due to deficient secretion in the alimentary canal, inaction of the liver, or insufficient contraction of the muscular fibers of the intestines), insufficient exercise, the use of alcohol or drugs, or improper food." [1]

Constipation may usually be counteracted by liberal drinking of water, especially a half hour before breakfast, and by eating food with laxative effect, — for example, ripe fruits (especially figs), green vegetables (especially salads with oil), and breads made of the coarser graham and rye flours.

Dyspepsia, also, is far too common, and is one of the most discouraging diseases to treat, because it shows itself in so many different ways. It is far easier to prevent than to cure, for it is usually caused by rapid or irregular eating, by taking indigestible foods, by lack of proper exercise, or by worry; and for all of these conditions the individual is, in the main, responsible.

The regulation of diet in time of sickness is a most important aid to recovery. In certain diseases it is necessary that some kinds of food should be forbidden. Whenever the functions of the body are not carried on with their accustomed vigor, the physician prescribes foods that are easily digested — for example, milk, raw oysters, toasted bread, and soft-boiled eggs.

146. The use of water as a drink. — "Many people, and especially many women, drink too little water. Water is constantly being lost through the lungs, skin, or kidneys, and this loss is only partially made good by the oxidation of the

[1] From New International Encyclopedia.

hydrogen of the protein's and fats. No rules as to the amount can be given, since it varies so much with temperature and the amount of muscular activity; but the habit of drinking no water between meals and but little at the table, in spite of popular opinion on the subject, is to be deprecated. . . .

"Undue emphasis has been laid upon the danger of drinking water with meals. The reasons given — that such water unduly dilutes the gastric juice or takes the place of a normal secretion of saliva — are questionable. As a matter of fact, the water thus taken is soon discharged into the intestine and absorbed. It is true, however, that the use of too much fluid with the meals is apt to lead to insufficient mastication because it makes it easier to swallow the food; and from this point of view caution is advisable. It is probably also true that much drinking with meals tends to overeating, by facilitating *rapid* eating." — HOUGH and SEDGWICK'S "Human Mechanism."

147. Effects of alcoholic drinks on the organs of digestion. — Alcohol, unlike most of the substances taken into the alimentary canal, requires no digestion. It can, therefore, be absorbed very rapidly by the blood, and hence alcohol is possibly sometimes of great value when administered by physicians, in cases when ordinary food cannot be digested. In health, however, alcoholic drinks must be regarded as an expensive and extremely dangerous source of energy.

According to the best authorities, small quantities of alcohol (when sufficiently diluted) seem for an adult to stimulate an increased flow of saliva and gastric juice, but even this is doubtful. The time required for the digestion of food, when alcohol is present in these small quantities, does not seem to be increased. Entirely different effects follow, however, when strong distilled liquors are taken,

and alcohol in any large quantity often produces serious disturbances of the organs of digestion. This is especially true when liquors are taken without food; that is, between meals. *The constant danger that the moderate use of beer and the light wines will lead to an uncontrollable thirst for alcohol cannot be emphasized too strongly. All authorities agree, too, that the growing youth should let alcohol entirely alone.*

148. Review of Digestion

Region of Alimentary Canal	Kind of Secretion Present	Processes Carried On
Mouth cavity.	Saliva and mucus	Mastication of food. Starch changed to sugar. Sugar and salt dissolved. Tasting of food substances. Small amount of absorption of water, salt, sugar.
Throat cavity.	Mucus.	Passage of food and air.
Gullet.	Mucus.	Passage of food to the stomach.

Region of Alimentary Canal	Kind of Secretion Present	Processes Carried On
Stomach.	Gastric juice, consisting of water, pepsin, and hydrochloric acid, and mucus.	Churning of food by the muscles. Digestion of starch (by saliva, for short time). Proteins changed to peptones. Insoluble salts changed to soluble. Small amount of absorption of water, salts, sugars, peptones.
Small intestine.	Pancreatic juice, bile, intestinal juices and mucus.	Fats changed to a liquid form ready for absorption. Starch changed to sugar. Proteins changed to peptones. Large amount of absorption of fats by lacteals of villi. Large amount of absorption of water, salt, sugar, peptones, by blood vessels of villi.
Large intestine.	Mucus, and intestinal juices	Small amount of absorption of nutrients. Removal of refuse of food from the body.

CHAPTER VI

CIRCULATION OF THE NUTRIENTS

I. Composition of the Blood

149. Food and blood. — Thus far in our laboratory studies we have tested various foods, and have found that they all consist of one or more of the nutrients; namely, proteins, fats, carbohydrates (*i.e.* starch and sugar), fats, mineral matters, and water. We have discussed the way in which each of these nutrients is digested, and thus made ready for absorption into the blood — for until the nutrients actually become a part of blood, they cannot be of use to the body. In **7** we described the *red* and *white corpuscles* of the blood[1] (Fig. 5) and there stated that the liquid part of blood is known as *blood plasma.*

150. Composition of blood plasma. — Blood plasma contains a large amount of water in which are dissolved the various nutrients obtained by absorption from the alimentary canal. The presence of each of these nutrients has been demonstrated by applying the various food tests given in **23–28,** "Plant Biology." Following is the percentage of each nutrient found in the human body: —

Water	90^{+}	per cent
Proteins	8^{+}	per cent
Fats, grape sugar, mineral matters	2^{-}	per cent

[1] For a laboratory study of blood, see Peabody's "Laboratory Exercises," pp. 50–53.

151. Hygiene of the plasma. — All the nutrition of the tissues is derived from the blood, and all the nutrients of the blood come from the foods we eat. If these foods are insufficient or of an improper kind, the blood will, of course, be deprived of necessary ingredients, and the cells must inevitably suffer in consequence. Hunger and thirst are the sensations that tell us that the blood is in need of new material. That this is true is demonstrated by the fact that these sensations disappear when water and liquid food, instead of being swallowed, are injected directly through the skin into the blood vessels.

152. Blood clotting. — When blood escapes from the body, it is a liquid of a bright red color. It soon changes to a dark maroon, however, and later this thickens to the consistency of jelly. This dark red mass is called a *blood clot*, and the process is known as *clotting* or *coagulation*. Coagulation is of great practical importance, since it provides a natural means of closing injured blood vessels, and of preventing loss of blood.

II. Circulation and its Organs

153. Necessity for the circulation. — From our study thus far, we have found that our bodies are composed of complex chemical compounds that are constantly being consumed in the development of heat and other forms of energy. It is evident, then, that every organ of the body, and indeed every living cell, must be supplied with new material to make good these losses and to provide for growth. The source of all this material is the food we eat.

In the last chapter we considered some of the processes by which foods are converted into liquid form and made ready for use in the cells. We found that after being liquefied these

nutrients are absorbed by the blood vessels in the walls of the alimentary canal. Since, however, many tissues of the body are at a considerable distance from the organs of digestion, it is evident that some means must be provided for supplying each cell with the nutrients it needs. This is effected by the circulation of the blood. *By the term circulation of the blood is meant the ceaseless movement of the blood through a system of tubes called blood vessels.*

154. Organs of circulation. — As is also true in the fish and other vertebrates, the force that drives the blood around through the body is largely furnished by the contraction of the muscular walls of the *heart.* Any blood vessel that carries blood away from the heart is called an *artery.*[1] The *veins* are the blood vessels that bring the blood back to the heart. Connecting the arteries and the veins in every part of the body are countless microscopic blood vessels called *capillaries* (Latin, *capillus* = hair, so called from their minute size). We shall now consider in more detail the structure and action of each of these circulatory organs.

III. The Heart

155. Position, size, shape. — The heart (Fig. 2) is a conical or pear-shaped organ about the size of the fist. It lies behind the breastbone near the middle of the chest cavity, with its pointed end or apex extending toward the left side between the fifth and sixth ribs. Since the beat of the heart is felt most plainly near the apex, it is commonly but wrongly believed that the heart lies on the left side of the body. Let one imagine the front wall of the chest

[1] From Greek, *aer* = air + *terein* = to hold — a name which was given by the early anatomists to these tubes, because they were found empty after death, and were therefore supposed to carry air.

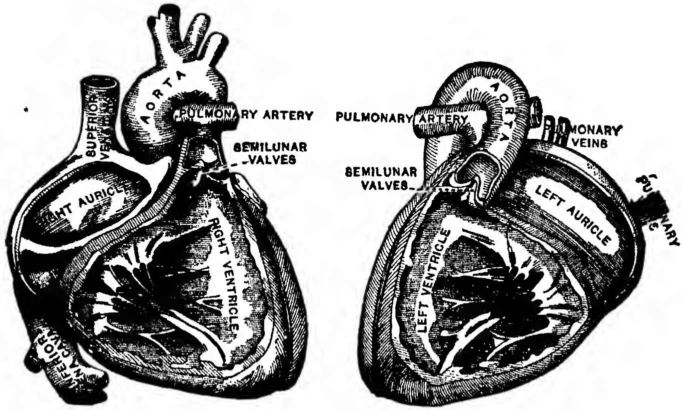
cavity to be removed; one would then see the soft, pink lungs on either side, nearly filling the chest cavity, and between them the heart [1] (Fig. 2).

156. Chambers of the heart. — We have seen (**A. B., 99**) that a fish's heart has two chambers, an *auricle* to receive the blood from all parts of the body, and a muscular *ventricle* to force the blood into the arteries which carry it to the organs of respiration (gills) and thence by another system of arteries to all parts of the fish's body. In the human circulatory system, the blood, after returning to the heart from the organs of the body, is likewise forced through an auricle, a ventricle, and arteries, and so reaches the breathing organs (*lungs*). Unlike the circulation in the fish, however, the blood does not pass from the breathing organs to the other parts of the body directly, but returns by veins to the heart, and so another auricle and ventricle are provided on the left side of the heart. These receive the blood from the organs of respiration, and force it to all parts of the body. Thus we see that we have two hearts, the chambers of which are completely separated by a muscular partition; the right heart receiving the blood from all over the body and pumping it to the lungs; the left heart receiving the blood from the lungs and pumping it over all the body.

A comparison of these four chambers shows important differences. In the first place, the auricles have relatively thin walls as compared with the ventricles, and the reason for this is evident when we see that their function is simply to receive the blood from the veins and to push it downward into the ventricles. When one compares the walls of the

[1] The heart is not only surrounded by the skeleton and muscles of the chest wall, but it is also inclosed in a tough bag of connective tissue called the *pericardium* (Greek, *peri* = around + *cardia* = heart).

left ventricle with those of the right, one is struck with the great thickness of the former. The left ventricle does much more work than the right; it forces blood to the top of the head, to the tips of the fingers and toes, and to every other organ of the body. The right ventricle, on the other hand, pumps blood only to the lungs (Fig. 33).

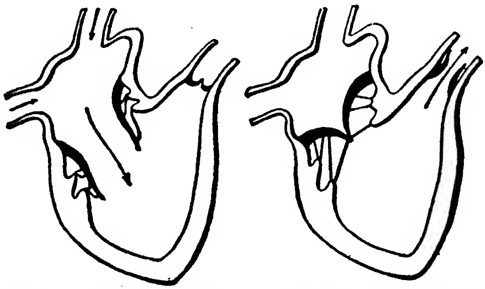


A = right heart. *B* = left heart.

Fig. 33. — Cavities of heart.

157. Action of the heart. — The blood flows into the right and left auricles and thence into the corresponding ventricles. When the ventricles are nearly full of blood, the two auricles contract and force downward enough blood to fill the two ventricles completely. These muscular chambers then contract and force the blood out into the arteries that lead to the lungs, or to other parts of the body. When the contraction of the ventricles takes place, it is evident that blood would be driven back into the auricles were there not some means of preventing this back flow. Hence, between each

auricle and ventricle tough flaps of membrane are provided which close the opening while the ventricles are contracting. Connected with each of these flaps are tough cords of tissue that are attached to the muscular walls of the ventricle. These cords prevent the valves from being forced up into the



A = positions of valves before the contraction of the ventricle.

B = position of valves at the beginning of the contraction of the ventricle.

FIG. 34.—Diagrams to show the action of the valves of the heart.

auricle (Fig. 34). When the ventricles cease to contract, the blood entering the auricles presses these valves downward and so enters the ventricles.

IV. THE BLOOD VESSELS

158. Position of arteries and the pulse. — We have defined an artery as a blood vessel carrying blood *from* the heart. Every time the ventricles contract, the arteries leading from them are expanded, and this is true of every artery in the body. Most arteries lie beneath thick layers of muscle or bone, which protect them from possible injury; but in certain regions of the body they lie close to the surface. If one places the fingers on the wrist two inches or more below the ball of the thumb, it is possible to feel a

distinct throbbing, called the *pulse*. This is due to the enlargement of the artery at each heart beat followed by subsequent contraction. When an artery is cut, therefore, the blood is forced out in spurts at each contraction of the ventricle.

159. Structure of arteries. — If a piece of the aorta of any animal is examined, it will be found that the blood vessel retains its tubular form, and this is due to the presence

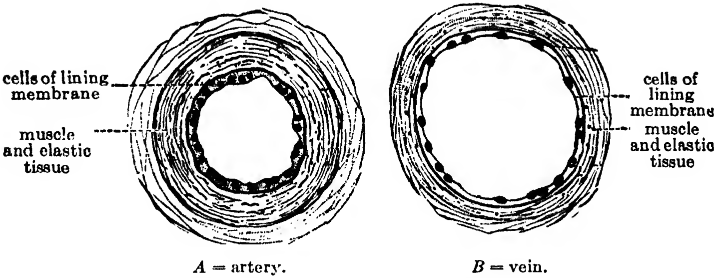


FIG. 35. — Cross section of blood vessels.

of thick layers of muscular and elastic tissue (Fig. 35). It is the elastic tissue that allows the arteries to expand when more blood is forced into them by the contraction of the ventricles. After each pulse these elastic walls squeeze the blood forward into the capillaries; arteries, therefore, are specially adapted to keep the capillaries full of blood.

The muscular tissue in the walls of the arteries aids in regulating the size of the arteries, and so determines the relative amount of blood supplied to any given organ. For example, when the face is flushed, the muscles in the arteries have relaxed; pallor, on the other hand, is due to the contraction of the muscular walls.

160. A study of the pulse. — Laboratory and home study.

A. To take the pulse. (Laboratory study.)

1. Place the fingers on the wrist as directed in **158**, and count the pulse while sitting quietly for a minute, being careful not to miss any of the beats. Repeat the count several times, until the numbers approximately agree. Describe what you have done, and record your pulse rate in your notebook.

2. (Optional.) In a table like the following record the number of pupils with a pulse rate (while sitting still) corresponding to the headings of the various columns named below.

40–49	50–59	60–69	70–79	80–89	90–99	100+

B. To determine the effect on the pulse rate of different positions of the body. (Home work).

1. Lie a few moments on a couch and completely relax the muscles. Count and record your pulse, repeating the count till the number during a minute is reasonably constant. (It is better, if possible, to have some one else do the counting.)
2. In a similar way, make a record of your pulse while sitting.
3. Determine, likewise, the pulse rate when you are standing.
4. Take some vigorous exercise for a few moments (*e.g.* running upstairs or riding a bicycle).[1] Now determine your pulse rate.
5. What do you conclude, therefore, as to the effect on the heart beat of vigorous muscular activity? In what ways may the rate of the heart beat be decreased?

161. Valves at the mouth of arteries. — The arteries are always full of blood, and when the ventricles contract, these

[1] In case the pupil has any heart difficulty, a milder form of exercise, such as walking rapidly or swinging the arms, should be taken.

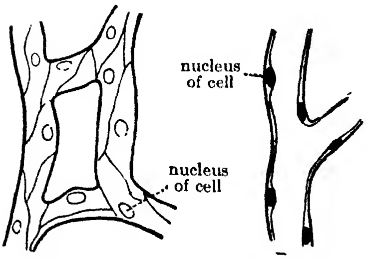
blood vessels have to be stretched in order to accommodate the additional blood that is forced into them. Hence, when the ventricles begin to relax, the blood tends to rush back into these chambers from the arteries. To prevent this, valves are placed at the opening of each of the two arteries that lead from the right and left hearts (Fig. 33). Each valve is shaped like a watch pocket. The three open outward from the heart, but as soon as the ventricles begin to relax, the blood fills up the pockets, and the three valves, by meeting in the middle of each artery, keep the blood from returning to the ventricles (Fig. 33, *A*).

162. Position of the capillaries. — As we trace the arteries farther and farther from the heart, we see that they divide and subdivide until very small branches are formed. That these fine branches are still arteries is proved by the fact that elastic and muscular tissues are present in their walls. Finally, however, these tiny blood vessels become continuous with still smaller tubes, the capillaries. So numerous are the capillaries that one cannot push the point of a needle for any considerable distance into any organ of the body without piercing a number of them. These smallest of blood vessels communicate freely with one another and form a complicated network of tubes that bring blood close to all cells of the body.

163. Importance of the capillaries. — If the blood were kept constantly within a system of tubes like the arteries, it would be entirely unable to help in the nutrition of the body because osmosis would be impossible. Each cell of the body must take from the blood the nutrients it needs for its special work; likewise it must give off to the blood the wastes it has formed by oxidation. It is through the thin-walled capillaries that all these exchanges of materials

occur. Hence, the capillaries form the most important portion of the blood system.

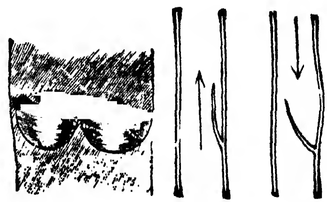
164. Structure of the capillaries. — In structure the capillaries are extremely simple (Fig. 36). At the points in the blood system where arteries end and capillaries begin, muscular and elastic tissues are wanting. The walls of the capillaries are formed of a single layer of very thin-walled cells. We have in this arrangement the best possible conditions for the process of osmosis. Only the thin membrane of the capillary wall separates the blood from the surrounding tissues, and an exchange of materials between the two is readily carried on.



A = Surface view. *B* = Longitudinal section.

Fig. 36. — Structure of capillaries.

165. Position of the veins. — On the back of the hand one sees through the skin a branching system of bluish blood vessels. These are veins. Unlike the arteries, veins have no pulse. Many veins, like those in the hand, lie near the surface, while most of the arteries, as we have stated above, are buried deeply among the other tissues.



A *B* *C*

Fig. 37. — Structure of a vein.

A = vein laid open to show shape of valves; *B* = section of vein showing valve open; *C* = section of vein showing valve closing.

166. Structure of veins. — When the veins are emptied of blood, they immediately collapse. This is due to the fact

that their walls have far less muscular and elastic tissue than have the walls of arteries. Veins, however, are provided with valves shaped much like the valves at the mouth of the large arteries leading from the heart. The blood can flow toward the heart, but as soon as it begins to pass in the opposite direction, these valves are immediately filled and thus the passage is obstructed (Fig. 37).

V. Circulation of the Blood

167. Course of the blood through the body. — Having completed our survey of the structure and action of the heart and the blood vessels, we are ready to study the blood system as a whole and to learn how the blood goes to, through, and from, the organs of the body. Let us now follow the course of the blood from the time it leaves the left ventricle until it again returns to this chamber of the heart. When the left ventricle contracts, the blood is forced out into the largest artery of the body, which is known as the *aorta*. This blood vessel forms an arch (Fig. 38) from the upper portion of which branches extend to the head and the arms. The aorta then continues downward through the chest and abdominal cavities, supplying on its way the various organs in these regions. It then divides into two arteries that continue down the legs. Each of these larger arteries that we have mentioned divides again and again, until finally the blood is forced through a network of very fine capillaries in the various organs to which the arteries extend.

From these capillaries blood passes into tiny veins which carry all the blood into two large veins, one from the upper part of the body, the other from the lower part of the body; and these two veins finally empty into the right auricle of the heart. Thence the blood passes into the right ventricle.

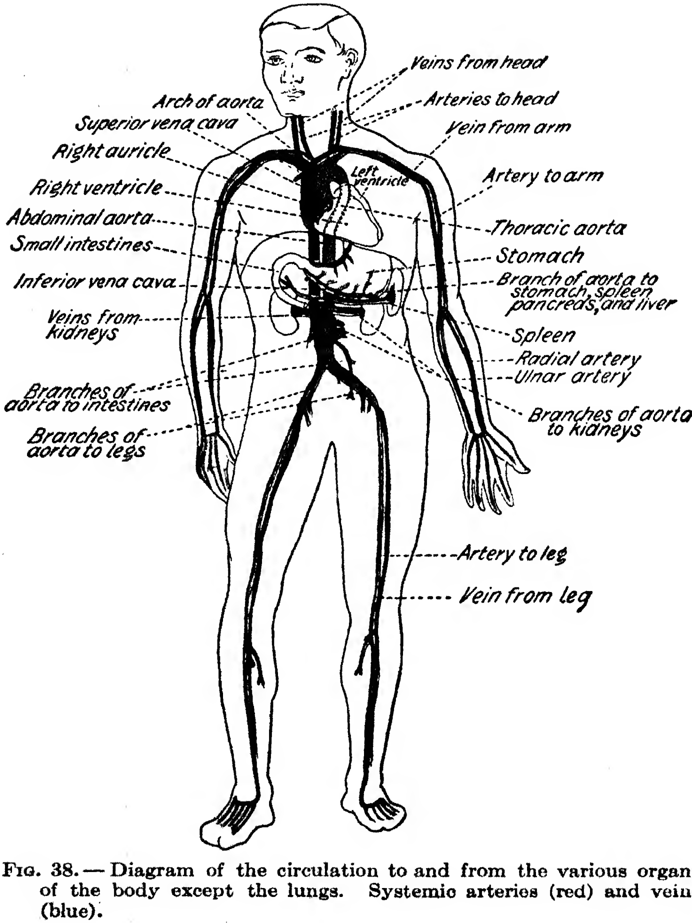


FIG. 38. — Diagram of the circulation to and from the various organs of the body except the lungs. Systemic arteries (red) and veins (blue).

The right ventricle by its contraction drives the blood through an artery to each of the lungs, until it finally reaches the countless capillaries in the interior of these organs. Veins now receive this blood and convey it to the left auricle, whence it again enters the left ventricle. About one half minute is required to complete the circulation.

168. Changes in the composition of the blood. — The composition of the blood is continually changing in its passage through the various tissues of the body. We may, perhaps, make clearer these various changes by expressing them in tabular form as follows: —

	Blood Loses	Blood Gains
In muscles, nerves, and other tissues.	Materials needed for growth, repair, and production of energy.	Wastes formed by oxidation (carbon dixoid, water, and other wastes).
In lining of mouth, stomach, intestines.	Materials needed for the manufacture of digestive juices and for growth and repair.	Digested nutrients.
In lungs.	Carbon dioxid and water.	Oxygen.
In kidneys and skin.	Water and other wastes.	Carbon dioxid.

VI. Hygiene of the Circulation

169. Effect of exercise on the heart. — The pulse rate is slowest when we are asleep. As the activities of the day begin, the heart beat is quickened, and after violent exercise

this organ may beat as often as twice a second. Exercise, when properly regulated, is undoubtedly beneficial to every organ of the body, for the heart should be kept in such a vigorous condition that it is ready to meet not only the ordinary requirements of everyday life, but even the strain that may come in such emergencies as necessary escape from danger or recovery from disease.

It is easily possible, however, to overstrain the heart muscle by exacting from this organ too violent or too prolonged activity (*e.g.* in sprinting or in long distance runs and bicycle rides). These often result in permanent thickening of the walls of the valves of the heart. Before a youth takes part in athletic contests, he should consult a competent physician as to the wisdom of his taking violent exercise.

170. Effect of exercise on the blood vessels. — When one is using the muscles actively, greater oxidation of the tissues goes on, and a larger amount of blood is needed to supply the oxygen and to remove the added wastes formed by this increased oxidation. The muscular walls of the arteries relax in the organs that are specially active, thus supplying these organs with more blood. It is manifestly impossible to have an increased supply of blood in the organs of digestion, in the muscles, and in the brain all at the same time. This is the reason why it is unhygienic for an adult to exercise violently or to carry on any considerable degree of mental activity immediately after a hearty meal. Persistence in violating this rule usually results in attacks of indigestion.

171. Stopping of blood flow in wounds. — One can tell when an artery has been cut by the fact that blood comes out in spurts. Since the blood is on its way from the heart, the flow can be stopped or lessened in this kind of accident

by applying pressure *on the side of the wound nearest the heart.*[1] Thus if the finger is cut deeply and the blood jets forth, a strong cord or a handkerchief should be tied loosely about the wrist, a wad of paper, or a pebble being placed directly beneath the knot and over the artery. A pencil or piece of wood should then be run through the loop, and the knot should be twisted until the blood flow is stopped by the pressure. When blood flows evenly from a wound, it is an indication that a vein has been cut, and the pressure should be applied in a similar way *on the side away from the heart.* If unable to decide whether an artery or a vein has been cut, put the bandage directly over the cut.[2]

Bleeding from the nose may usually be stopped by holding the head erect, and by applying cold water to the bridge of the nose or to the back of the neck.

[1] Every pupil should practice the method of applying a bandage in accordance with the directions given in this section.

[2] For further treatment of cuts and bruises see **25.**

CHAPTER VII

RESPIRATION AND THE RELEASE OF ENERGY IN MAN

I. Necessity for Respiration

172. To prove that oxidation takes place in the human body.[1] — Laboratory study.

A. Development of heat in the human body.

Secure two chemical thermometers that approximately agree at the room temperature. Support one of the thermometers so that it hangs free in the air; clasp the bulb of the other thermometer in the palm of the hand for several minutes.

1. Describe the experiment as it was performed.
2. Note and record the temperature as indicated on each of the thermometers.
3. What evidence have you that heat is produced in the human body?

B. Production of carbon dioxid in the human body.

Blow the breath through a tube into a bottle or test tube of lime water.

1. Describe what was done.
2. What proof have you that carbon dioxid is given off from the body?
3. What element found in foods and protoplasm must be oxidized in order to produce carbon dioxid?

[1] The student should review **P. B., 75** (to prove that heat energy is developed in growing seedlings) and **P. B., 81** (to prove that carbon dioxid is formed during the growth of seedlings).

4. State now two evidences that oxidation is carried on in the human body.
5. What element must always be present in order that oxidation may be carried on?

173. Examples of energy in the human body. — While studying plants, we enumerated various ways in which these living organisms exhibit the energy which is developed within them (**P. B., 74**), and we have likewise called attention to evidences of energy in animals. In human beings the forms of energy are much more varied and striking. For example, the movements of each of the five hundred separate muscles found in the body are all due to the *muscular energy* developed in their protoplasm; the control of all these muscles is due to energy liberated in the nervous system (*nervous energy*); all the glands that produce the varied ferments owe their ability to do their work to the release of *chemical energy;* and when we come to deal with the highest functions, namely, feeling, thinking, and willing, it seems probable that all of them are made possible by the setting free of some form of energy. In connection with the development of all these forms of energy, heat energy, as we proved in **172**, is liberated.

174. Transformations of energy. — While considering the functions of green plants we found that the energy of the sun is utilized and stored in the manufacture of food materials, and thus is made available for the use of the plant. Consequently, when we take into our bodies and digest the various nutrients produced by green plants, these food substances become available as our sources of energy. But to release this stored-up energy, whether in muscle, gland, or nerve cells, oxygen is always essential. Hence, a constant supply of oxygen for the body is necessary. When this oxygen

combines, in the process of oxidation, with the carbon, hydrogen, and other elements in the foods or protoplasm, waste matters (carbon dioxid, water, etc.) are produced, and for the healthy working of the body, these wastes must be eliminated. We are now to see how the body is adapted to secure an adequate supply of oxygen and to rid itself of harmful waste matters.

175. Respiration in plants, animals, and man. — It should be clear from our study thus far that all living things require oxygen, and that this oxygen brings about in plants, animals, and man a process resembling oxidation, at least in the releasing of heat and of other forms of energy, and in the production of carbon dioxid and other waste matters. These various processes doubtless take place in each living cell. Hence, every cell must be supplied with oxygen and must necessarily form carbon dioxid. *The process by which plants or animals take in oxygen and get rid of carbon dioxid is known as breathing.* And when we include also the oxidation that takes place within the cells and the elimination of the wastes from the cells, this whole series of processes is known as *respiration.*

Breathing involves two distinct processes; first, that of taking into the lungs new supplies of fresh air, and secondly, that of removing from the lungs the impure air that has been used. To the first process is given the name *inspiration* (Latin, *in* = into + *spirare* = to breathe); the second is called *expiration* (Latin, *ex* = out + *spirare* = to breathe).

II. Adaptations for Securing Oxygen and for Excreting Carbon Dioxid

176. Course taken by the air. — In ordinary breathing, air enters the body through the two nostrils (the left one is

shown in Fig. 39), and then through the two nasal passages it enters the throat cavity. In the lower region of the throat is the slit-like *glottis opening*, through which the air enters the *larynx* or voice box. The latter, commonly known as "Adam's apple," projects somewhat on the front of the neck. Below the larynx is the continuation of the windpipe, which, just above the level of the heart, divides into two main branches (Fig. 40), one of which supplies air to the right lung, the other to the left lung. Within the lungs these tubes branch off into a vast number of very small pipes, called *bronchial tubes*. The finest divisions of these tubes open into extremely thin-walled *air sacs* (Fig. 41).

Fig. 39. — Longitudinal section of head and neck showing food and air passages.

a = vertebral column.
b = gullet.
c = windpipe.
d = larynx.
e = epiglottis.
f = uvula.
g = opening of left Eustachian tube.
h = opening to tear duct.
k = tongue.
l = hard palate.

177. The nose cavity. — The openings into the nasal passages are guarded by a mass of projecting hairs, by means of which a considerable amount of dust is kept from entering the lungs. The nose itself is lined by mucous membrane which covers the whole interior of the nasal chambers. Its mucous secretion collects most of the dirt and germs that have passed the hairs in the nostrils.

178. The throat and larynx. — Except when something is being swallowed, the glottis is always open, thus allowing a free passage for the air from the throat, through the larynx, into the windpipe. When food is swallowed, it is of course important that the windpipe be closed, and this is accomplished by a little trapdoor called the *epiglottis* (Fig. 39). If one puts the finger on the larynx region and then swallows, one can feel this organ rising to meet the epiglottis. Within the voice box are two thin membranes that may be stretched with more or less tension and set in vibration by the inspired or expired air. These *vocal cords* help to produce the various tones of the voice.

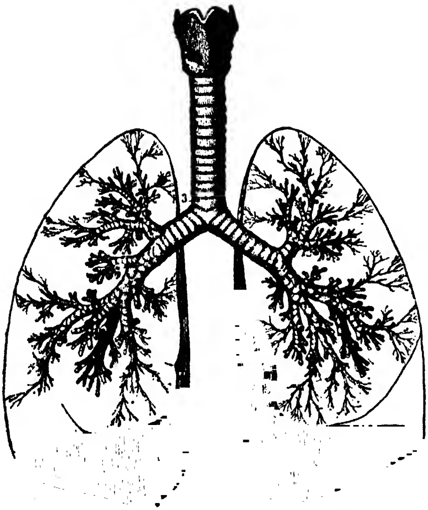


FIG. 40. — Windpipe and lungs.

FIG. 41. — Two air sacs with their branches.

179. Lining of the air passages. — The mucous lining of the nasal cavities and of the windpipe and its branches is especially interesting. The cells that cover these passageways are covered by minute hair-like projections called *cilia*, much like those on the outside of a paramecium (**A. B., 120**), which wave upward toward

the throat with a quick movement, and then more slowly recover their former position (Fig. 18). In this way any dust particles that have passed the barrier of hairs at the nostril openings and the mucus secreted by the membrane are moved steadily upward until they reach a point where they can be coughed out into the mouth cavity.

180. The lungs.[1] — When the finest branches of the bronchial tubes are traced, we find that each one ends in a branching *air sac* with extremely thin walls of elastic tissue (Fig. 41). When air comes into these sacs, they are expanded; but as expiration begins, their elastic walls help to force back through the branches of the windpipe the air that has been taken into the lungs.

181. Blood supply to the lungs. — The artery supplying the lungs, as we learned (**167**), arises from the right ventricle and soon divides into two branches, one for the right and one for the left lung. Within the lung tissue each artery divides into small branches that follow the course of the bronchial tubes to the air sacs. Here the arteries communicate with a maze of capillaries that run just beneath the thin lining of the air sacs. It is here that the exchange of material takes place between the blood and the inhaled air, for the two are separated only by the extremely thin

[1] One can get a good idea of the structure of the human air passages and lungs by securing from the butcher the chest organs of a sheep or calf. These consist of the larynx, windpipe, and its branches, and the two lungs, between which lies the heart. A piece of the diaphragm should also be secured if possible. The lungs are composed of soft, pink tissue, easily compressed by the hands. If air is forced through a tube inserted in the glottis opening, the lungs swell, and when fully distended occupy a space several times their size when collapsed. Just as soon as one ceases to blow into the lungs, these organs begin to collapse, and soon reach their former condition. The characteristics of the lungs and air passages should be demonstrated before **180** is assigned for study.

walls of the air sacs and of the capillaries. From the capillaries of the lungs, the blood finally collects into veins that convey the blood to the left auricle.

182. The function of red corpuscles. — In 7 we called attention to the structure of the red corpuscles of the blood. Like other cells red corpuscles are composed of protoplasm. Chemical analysis shows that the most important ingredient is a protein substance called *hemoglobin*, a compound that contains iron. Hemoglobin gives the red color to the blood and has a remarkable power of combining with oxygen when that element is abundant, and of giving it up wherever it is needed in the various parts of the body. We may, therefore, compare the blood corpuscles to countless little boats, floating in a stream of plasma; they take on their cargo of oxygen from the air in the lungs and discharge it in the cells of the tissues.

183. Change in the color of the blood after mixing with oxygen. — When the blood passes through the lungs, as already stated, it absorbs oxygen. The resulting change in color is seen from the following experiment. Pour into a glass bottle a small amount of blood that has been prevented from clotting by stirring it vigorously with a bunch of twigs, and stopper tightly. When the bottle is shaken violently, the blood is mixed with the oxygen in the bottle, and the dark maroon color changes almost instantly to a bright scarlet. The pupil will doubtless have observed that the blood in the veins on the back of the hand, for instance, is blue, but that whenever blood flows from any of these veins because of a slight cut, the color is always bright red after the blood comes in contact with the oxygen of the air.

184. Hygiene of the red corpuscles. — Since supplying oxygen to the various tissues is the function of the red cor-

puscles, it is very important that their number be sufficient and that they be kept in a healthy condition. To this end, *an abundance of sleep, exercise, fresh air, and nutritious foods are the essential conditions.* Every one is familiar with the fact that the face looks pale after loss of sleep, or when food and fresh air are insufficient, or during periods of physical inactivity, and this appearance indicates a lack of red corpuscles. Habitual paleness, or *a-næ'mi-a,* is a disease requiring medical treatment. It is frequently due to a want of iron in the system; hence, the value of spinach and other vegetable foods containing this element. Fresh air, a moderate amount of exercise, and good food are usually the best remedies for anæmia. A good complexion is, therefore, very largely dependent on healthy blood. Paint, powder, and other cosmetics will not give such a complexion; and besides cheapening the individual who uses them habitually, they are often a source of permanent injury to the skin and blood.

III. The Process of Breathing

185. Structure of the chest cavity. — In the upper portion of the trunk is the cone-shaped chest cavity, which is more or less inclosed by the breastbone, the ribs, the collar bones, and the spinal column. This bony framework is covered by muscles that help to move the ribs, and by the outside covering of skin. The floor of the chest cavity is formed by the tough sheet of muscle and connective tissue, the diaphragm. In this way there is formed an air-tight compartment, which is completely filled by the heart, the blood vessels, the gullet, and the lungs (Figs. 1 and 2).

186. The pleura. — The outer surface of each lung is covered with a thin layer of membrane, and the walls of the chest cavity are lined with the same kind of tissue. These two layers constitute

the *pleura*. Both surfaces secrete a liquid which enables the lungs to glide over the chest wall without friction.

187. To determine the amount of enlargement of the chest cavity during inspiration. — (Home work.)

Force the air out of the lungs as completely as possible. Draw a tape or cord around the chest under the armpits, keeping it reasonably tight, and thus measure the girth of the chest.

1. State what you have done, and record in inches the measurement thus determined.
2. Inhale as much air as possible, and again record the chest measurement as directed above.
3. State the difference in the measurements thus obtained.
4. What is your conclusion, therefore, as to the amount of enlargement of the chest cavity?

188. How air is taken into the lungs. — The chest cavity is not like most boxes inclosed by rigid, immovable walls, for it may be enlarged in its three dimensions; namely, from side to side, from front to back, and from top to bottom. We shall now consider how this is made possible. A study of the skeleton will show that the ribs are joined to the vertebræ in the back of the chest region and to the breastbone in front in such a way that it is possible to raise and lower the front ends. When the air is forced out of the chest cavity, the front ends of the ribs are lowered and so the breastbone is pulled nearer to the spinal column. As we inspire, the muscles that run from the upper part of the trunk to each of the ribs contract, and so these bones are pulled upward toward a horizontal position. By this movement the breastbone is pushed farther away from the spinal column, and the ribs themselves press outward at the sides. In this way the capacity of the chest cavity is increased from side to side, and from front to back.

When the diaphragm is at rest, it forms a dome-shaped partition between the organs of the chest and those of the abdomen (Fig. 42). During inspiration, the muscles of which the diaphragm is largely composed, are made to contract, the dome of this organ becomes flattened, and so presses down upon the stomach, liver, and other abdominal organs, and these in turn force outward the wall of the abdomen. By the action just described, the size of the chest cavity is increased in its third dimension; namely, from top to bottom.

Thus, by the combined movements of the ribs and diaphragm, the chest cavity is enlarged in all three of its dimensions. The walls of the chest cavity would, therefore, tend to move away from the lungs; but the air already in the lungs expands the many air sacs in the lung tissue, and so keeps these organs in close contact with the chest walls. The moment, however, that the air sacs begin to enlarge, the air expands to fill the larger space, and so the pressure of the air on every square inch inside the lungs is diminished, and therefore becomes less than the air pressure outside the body. At once more air is forced in through the air passages until the pressure within and outside the body becomes equalized. This process we have described is called *inspiration*. Every inspiration requires muscular action in elevating the ribs and flattening the diaphragm.

189. To determine the breathing capacity of the lungs. — Laboratory demonstration.

Fill a large tray half full of water. Mark on a gallon bottle the level of 1, 2, 3, and 4 quarts; completely fill the bottle with water, and invert it in the tray, just as was done in collecting oxygen and other gases (**P. B.**, **10**). Beneath the mouth of the bottle insert one end of a glass or rubber tube. Now take in a deep inspiration, filling all parts of the

lungs as completely as possible, then slowly exhale, blowing the breath through the tube. Make sure that only one complete expiration is carried on, and take care that all the expired air is collected in the bottle.

1. Describe the way the experiment was carried on.
2. Note the number of quarts occupied by the expired air in the bottle, and record this in your notebook.
3. What do you conclude, therefore, as to the amount of air that may be forced out of the two lungs of the individual who performed the experiment?

4. (Optional.) Ask the pupil who has the highest record of difference in chest measurement before and after inspiration (**187**) and also the student who has the least difference in the two figures, to try the experiment. State whether or not there is a correspondence between chest enlargement and lung capacity.

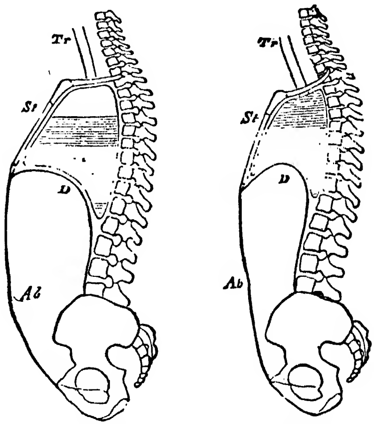
190. How air is forced out of the lungs. — As soon as the muscles that cause the upward movement of the ribs and the downward movement of the diaphragm begin to relax, the ribs sink back into their former position, the breastbone is pulled back into place, and the distended wall of the abdomen presses the organs upward against the diaphragm, which therefore becomes more arched (Fig. 42). In all these ways the walls of the chest cavity close in upon the lungs, and thus help their elastic tissue to force out the air in expiration. Ordinary expiration is thus accomplished without muscular effort.

IV. Hygiene of the Respiratory Organs

191. Hygienic habits of breathing. — We have called attention to the admirable provisions in the nose for filtering the air. Air is likewise warmed and moistened by the mucous membrane of the nose. This is necessary, because very cold or very dry air is irritating to the air passages

and the lungs. Less efficient arrangements for this purpose are found in the mouth cavity. Hence, if one breathes through the mouth, one is likely to take in considerable quantities of dust and bacteria, which may, in time, cause inflammation or other forms of disease.

192. Effect of exercise on respiration. — Not only does the heart beat more rapidly during exercise, but the rate of breathing also increases. Oxygen is thus supplied to the cells in larger quantities, and more wastes are eliminated. Deep breathing is a prime requisite for healthful living, since in this way the air is changed throughout the lungs. In short, quick breathing, on the other hand, it is only the air in the upper regions of the lungs that is thus affected. The "second wind" that the runner gets after a short time is due to the expansion of all portions of the lung tissue. In order to keep the chest walls flexible and capable of full enlargement, a certain amount of regular exercise should be persisted in throughout life.



A = inspiration. *B* = expiration.

FIG. 42. — Diagram to show changes in the size of the chest cavity during inspiration and expiration.

Ab = abdominal wall.
D = diaphragm.
St = breastbone.
Tr = windpipe.

193. Effect of tight clothing upon respiration. — In an earlier part of this chapter we learned that air is forced into the lungs when the front ends of the ribs are elevated and the

lungs as completely as possible, then slowly exhale, blowing the breath through the tube. Make sure that only one complete expiration is carried on, and take care that all the expired air is collected in the bottle.

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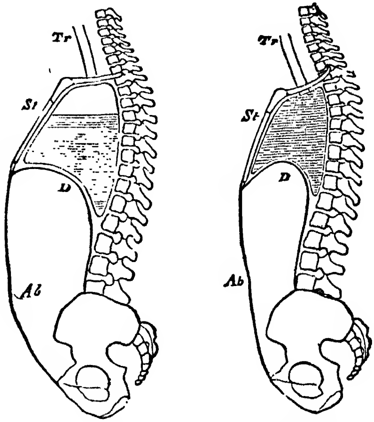

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193. Effect of tight clothing upon respiration. — In an earlier part of this chapter we learned that air is forced into the lungs when the front ends of the ribs are elevated and the

diaphragm is pulled downward toward the horizontal position. By no other means are the respiratory organs filled with air, and any interference with the action of either ribs or diaphragm tends to decrease the supply of oxygen and the excretion of carbon dioxid, and to increase the chances of disease in these organs. Tight clothing about the chest and abdomen not only results in permanent distortion of the skeleton (Fig. 46), but also it retards the movements by which the chest cavity is enlarged. Shortness of breath and inability to perform any great amount of muscular exercise are some of the ill effects that are experienced from tight lacing. Diseased conditions of the organs, too, may be brought about when they are thus compressed and forced out of position. It is especially important that loose clothing be worn in the gymnasium, or during any vigorous exercise, in order that the muscles used in motion and respiration may be free to work unhampered.

194. Diseases of the respiratory organs. — In **26–34** we discussed the cause, treatment, and prevention of pneumonia, diphtheria, and tuberculosis, all of which affect the organs of respiration. We shall now call attention to some other diseased conditions often found in these parts of our bodies. *Catarrh* is an inflammation of the mucous membranes of the throat and nose, and it sometimes becomes so bad that these air passages are more or less closed, and it causes a very disagreeable breath.

Within the nose and throat cavities projections from the walls frequently develop, which at times practically close these air passages and compel the individual to breathe through the mouth. These are known as *adenoids*. Between the mouth and throat cavities lie the *tonsils;* if these become unduly enlarged, and inflammation sets in, *tonsillitis*

results. As soon as catarrh or enlarged tonsils or adenoids are discovered, the advice of a competent physician should be sought, for these diseases of the air passages prevent an adequate supply of air from reaching the lungs and tissues, and seriously interfere with the normal development of the body and mind.

Colds are inflammations of the air passages or of other regions of the body, and they are probably due to the action of bacteria. If the malady is confined to the nose cavity, we call it a cold in the head; if it is seated in the throat, a sore throat results; a cold on the chest is an inflammation of the windpipe or its subdivisions. When the bronchial tubes are affected, their lining membrane becomes swollen, and the air passages are more or less closed; this is *bronchitis*. And finally, if the inflammation affects the air sacs, *pneumonia* results.

195. Suffocation. — We have often called attention to the fact that the body must be supplied continually with oxygen and that its wastes must be constantly removed. If this process is interrupted, even for five minutes, fatal results are almost sure to follow. If, in swallowing, food gets past the epiglottis into the windpipe, *choking* results. In cases of this kind the head should be held forward (or downward in case of a child) and sharp blows struck between the shoulders. By *suf-fo-ca'tion* is meant some interference with the process of breathing. Suffocation may be due to inclosure in a small space with a limited supply of oxygen, to the inhaling of poisonous gases, or to immersion in water (drowning). In any case, the patient should be brought out at once into fresh air. If water has entered the air passages, the person should be turned face downward. One should then stand astride him and support the weight of his

body by clasping the hands beneath his abdomen. In this position the water can flow out of his lungs more easily. If respiration is feeble, cold water should be applied to his face, and his chest should be slapped vigorously. If all these methods fail to restore vitality, and if the aid of a physician cannot be immediately secured, *artificial respiration* should be attempted at once.[1] This is accomplished by laying the patient on his back, with a rolled coat or other support beneath his shoulders. His mouth should be opened and his tongue drawn out. His arms should then be grasped firmly at the elbows and pulled upward and parallel to each other until they lie above the head. In this way air is drawn in through the nose and mouth. When the elbows are carried downward and pressed upon the chest, the air is forced out of the body. These two movements should be alternated regularly every few seconds, and hope of resuscitation should not be abandoned until several hours have elapsed.

196. Necessity of ventilation. — Every act of respiration removes oxygen from the air taken into the body, and adds to the air carbon dioxid and certain poisonous organic compounds. One might breathe in this air a second time and still be able to extract oxygen from it. The presence of chemically pure carbon dioxid in air even in considerable quantity is not necessarily dangerous; but to take into the body again the organic wastes that have once been given off is most unhealthful. The first effect of foul air is a feeling of sleepiness, followed by headache, and if larger quantities are breathed in, the body becomes poisoned. We see, then, the absolute necessity of having the air in a living room

[1] Pupils should learn by actual practice on one another at home the movements necessary for causing artificial respiration.

changed frequently. *The air that has been once used must be removed and a fresh supply must be furnished; this is what is meant by ven-ti-la'tion.*

197. Methods of ventilation. — It is important to remember that fresh air is not necessarily cold air, and that draughts of air in a room are not required; indeed, that they are undesirable. The problem of ventilation is that of furnishing a sufficient quantity of wholesome air of the proper temperature and moisture and of removing the foul air. It is evident that this is rather difficult to accomplish in schoolrooms or in public halls. Air will not of itself circulate rapidly enough, and so it has to be forced into these rooms by large blowers or revolving fans in the basement. This air should be filtered and moistened. Hot-air pipes or fans are likewise often employed at the top of the ventilating flues to draw out the foul air. Since warm air is lighter than cool air, the former should enter a room near the ceiling. As it cools it gradually settles toward the floor, and the openings into the ventilating shafts should be found at the lower part of the room. If the system works properly, there will be a continuous supply of clean, warm, moist air, and at the same time the air that has once been used will be drawn off through the flues.

Unfortunately, in most of our dwelling houses, little provision has been made by the builders for proper ventilation. Hence, if the rooms are heated by steam, we frequently breathe the same air over and over. This may be obviated, however, by ventilating in the following way. A piece of board two or three inches wide should be fitted across the lower end of the window opening. When the lower sash is pulled down upon it, a space is left between the upper and lower sashes, through which fresh air may enter the room

without causing a direct draught. In order to secure a proper circulation of air an opening of equal size should be provided by lowering the top sash of the window.

Furnace heat is much more satisfactory than steam from the point of view of ventilation, for in this way a continual supply of fresh, warm air may be furnished. An open fireplace is one of the best means of removing foul air, and when a fire is burning, a strong current up chimney is assured. We have called attention to the fact that dry heat tends to cause catarrh and other diseases of the air passages. Provision should therefore be made to keep the air in rooms moist. This may be partially accomplished by keeping the water pans in a furnace full of water, or by leaving trays of water on steam or hot water radiators.

CHAPTER VIII

ADDITIONAL TOPICS IN HUMAN BIOLOGY

I. The Skin

198. Characteristics of the skin. — The whole outer surface of our bodies is incased in a flexible, elastic skin of varying thickness and texture. In regions like the palm of the hand and the sole of the foot, for instance, the skin is thick and tough; the covering of the lips, on the other hand, is extremely thin. At the ends of the fingers and toes are the nails. All other parts of the body, with the exception of the palms of the hands and the soles of the feet, have a covering of hair. Both the hair and the nails are modified parts of the skin.

199. Uses of the skin. — The most obvious use of the skin is the protection that it affords to the muscles and other organs that lie beneath. In the second place, it has a countless number of sense organs which receive messages from the outside of the body. These are carried along nerve fibers to the spinal cord and brain, and then we get impressions of temperature, of pressure, and of pain. In the third place, by means of the perspiratory action of the skin, the body throws off a great deal of water and small quantities of other waste matters. And, finally, as a result of the evaporation of this water from its outer surface, the body loses its surplus of heat, and so keeps an even temperature of 98.6° F.

As we might infer from all these uses, the skin is a complex organ composed of several tissues. We shall now study its structure and see how it is adapted to perform the *four functions* that we have just enumerated.

200. Layers of the skin. — The skin everywhere consists of two different layers: an outer, called the *ep-i-der'mis* (Greek *epi* = upon

\+ *derma* = skin), and an inner, the *der'mis* (Fig. 43). When one gets a blister by burning the skin, most of the epidermis is lifted up by an excessive amount of watery fluid that comes from the blood. In a blister one can easily distinguish the white epidermis from the pink layers of the dermis lying beneath.

201. Glands of the skin. — Two kinds of glands are found in the skin; namely, the *oil glands* and the *sweat* or *per-spi'ra-to-ry glands.*

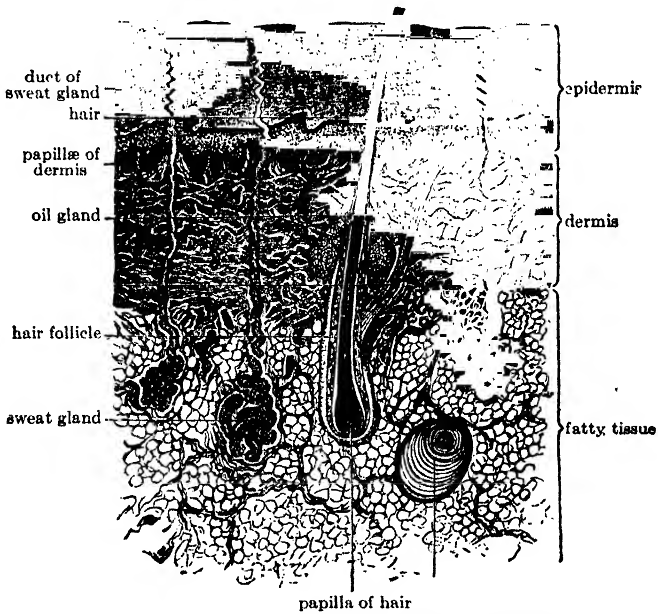


FIG. 43. — Vertical section of scalp, highly magnified.

The former are found in most parts of the skin, being most numerous in the scalp and in the skin of the face. Like hairs, however, oil glands are wanting on the palms of the hands and the soles of the feet. Sweat glands, on the other hand, are most numerous in the regions just named. One writer estimates that there are 2800 sweat

pores on every square inch of the surface of the palm, and that the total number of these glands in one's skin is about 2,500,000.

202. Importance of bathing. — The oil glands and perspiratory glands are constantly pouring their secretions in greater or less quantity upon the skin. As the water evaporates, the oil and the solid ingredients of the sweat are left behind. Unless these are removed, they tend to clog the openings of the ducts from the glands and so to interfere with the work of the skin. A considerable amount of these substances is doubtless worn away, together with the scales of the outer skin, by friction against the clothing. But if the skin is to carry on its functions to the best advantage, and if decency is to be maintained, frequent baths must be taken.

203. Kinds of baths. — The oily secretions and much of the accumulated dirt on exposed surfaces of the skin can be removed only by the use of warm water and soap; hence these should be employed upon the hands two or three times a day and at least once or twice a week upon the whole body. *Warm baths* should be employed, however, for their cleansing effect only, since they are usually followed by a feeling of lassitude. One is much more likely to catch cold, too, after exposure to warm water, as it opens the pores of the skin, causes the arteries near the surface to dilate, and thus increases the amount of perspiration. Unless the warm bath is taken just before going to bed, it should be followed by a quick application of cold water.

Cold baths, on the other hand, if taken under proper conditions, have an exhilarating effect. The body should then be rubbed vigorously with a coarse towel. If after a cold bath one does not feel a warm glow, the bath is injurious rather than beneficial.

Baths should never be taken immediately after eating, since the blood is thereby drawn away from the organs of digestion. Nor should one remain in cold water until one feels a chill. *Shower baths*, however, are better than a cold plunge, for they stimulate both by the cool temperature of the water and by the force with which it strikes the skin.

204. Care of the hair. — The oil glands are most numerous in the scalp, and if the skin is in a healthy condition, the hair is supplied

with the proper amount of oil. If this secretion dries, however, and becomes mixed with the loose outer scales of the epidermis, *dandruff* is caused, and this should be removed by vigorous brushing and shampooing. Not only is the scalp cleaned in both of these ways (if clean brushes and combs are used), but the friction stimulates the circulation of the blood through the scalp, and good blood is a better hair tonic than any external application. If the oil supply is insufficient and the hair becomes dry, vaseline may be used. The scalp should be well dried after a bath, for moisture at the roots of the hair tends to cause decomposition. Brushes and combs should be kept scrupulously clean.

205. Care of the nails. — One of the surest means of detecting slovenly personal habits is by watching the care an individual takes of his finger nails. An accumulation of dirt beneath the nails or jagged edges caused by biting the nails almost always indicate a lack of good breeding. The finger nails should be carefully cleaned with soap, water, and a nail brush or with a nail cleaner, but never with a penknife or scissors, for metal scratches the surface and makes a place for the lodgment of dirt. The roll of epidermis about the base of the nail should frequently be moistened and pushed back; otherwise this outer skin is likely to become torn and to form the so-called "hangnails." These are often a source of great discomfort and sometimes of danger, for they furnish a possible opening for infection by bacteria.

206. Treatment of burns. — We have already suggested the treatment for cuts and bruises of the skin in **25**. Another form of accident that may injure the skin is a burn. The affected part should be covered and bandaged with a paste of baking soda, which tends to lessen the pain by keeping out the air. A mixture (known as *carron oil*), half linseed oil and half limewater, is also a good remedy to keep on hand for burns. If, however, the skin is broken, the wound should be treated with an antiseptic. When the clothing of a person catches fire, the flames should be extinguished by wrapping him quickly in thick clothing or pieces of carpet.

207. Clothing. — The warmth of certain kinds of cloth depends upon the fact that they keep the heat of the body from escaping; in other words, they are poor conductors of heat. Good conductors, on the other hand, allow the heat to pass off rapidly. This difference in fabrics is largely due to the way they are woven. Wool, for instance, is usually made into cloth that is loose in texture, and thus it can hold a considerable amount of air in its meshes. Now, dry air is a poor conductor of heat. Woolen clothing is, therefore, generally used for winter wear. Cotton and linen are tightly woven, and heat radiation through these materials is rapid. When this takes place, the blood is likely to be driven away from the surface of the body, thus causing a congestion of blood in the internal organs, which is a favorable condition for such diseases as colds, pneumonia, or consumption. The same result often follows the wearing of wet clothing, since wet clothing is a good conductor of heat.

208. Effect of alcohol on body temperature. — "The action of alcohol in *lowering the temperature*, even in moderate doses, is most important. By dilating the cutaneous vessels, it thus permits of the radiating of much heat from the blood. When the action is pushed too far, and especially when this is combined with the action of great cold, its use is to be condemned."[1]

"A party of engineers were surveying in the Sierra Nevadas. They camped at a great height above the sea level, where the air was very cold, and they were chilled and uncomfortable. Some of them drank a little whisky, and felt less uncomfortable; some of them drank a lot of whisky, and went to bed feeling very jolly and comfortable indeed. But in the morning the men who had not taken any whisky got up in a good condition; those who had taken a little whisky got up feeling very miserable; the men who had taken a lot of whisky did not get up at all: they were simply frozen to death. They had warmed the surface of their bodies at the expense of their internal organs."[2]

[1] Landois and Stirling, "Textbook of Human Physiology."
[2] T. Lauder Brunton, London, "Lectures on the Action of Medicine."

II. The Skeleton

209. Necessity for the skeleton. — Most of the common animals with which we are familiar have some kind of skeleton that serves as a means of protection, of support, or of locomotion. In some animals, *e.g.* clams and lobsters, the skeleton is on the outside; in the vertebrates, on the other hand, the skeleton is internal. A study of Figure 44 will make clear the general arrangement of the skeleton of man. The position and general shape of the bones may be determined by the pupil from a study of his own body. For convenience, the two hundred bones of the skeleton may be divided into three groups, namely, (1) the bones of the neck and trunk, (2) the bones of the arms and legs, and (3) the bones of the head.

210. The skeleton of the neck and trunk. — The erect position of the adult human body is maintained by a column of bones called *vertebræ.* The spinal column may be felt through the skin behind the neck and down the middle of the back. The human spinal column is a wonderful piece of mechanism, which by its structure is adapted to perform at the same time three distinct functions. In the first place, the vertebræ, piled one on the other, form a column strong enough to support the weight of the body. Again, the structure of the spinal column shows marvelous provisions for securing elasticity and freedom of motion. Elasticity is secured by a succession of four curves which are best seen in a side view of the body. By means of these curves the head and the upper part of the trunk are saved from sudden shocks that would result from running or jumping, for the curves act like a series of springs. Pads of cartilage between the vertebræ serve as cushions to prevent jarring. This general arrangement of the spinal column permits a considerable range of movement.

A third adaptation that is evident in the structure of the spinal column is the protection it affords to the delicate spinal cord (**231**) which is inclosed by it in a continuous tube. One would search far before finding a more perfect means of securing strength, elasticity, and flexibility than that provided in the structure of the human spinal column.

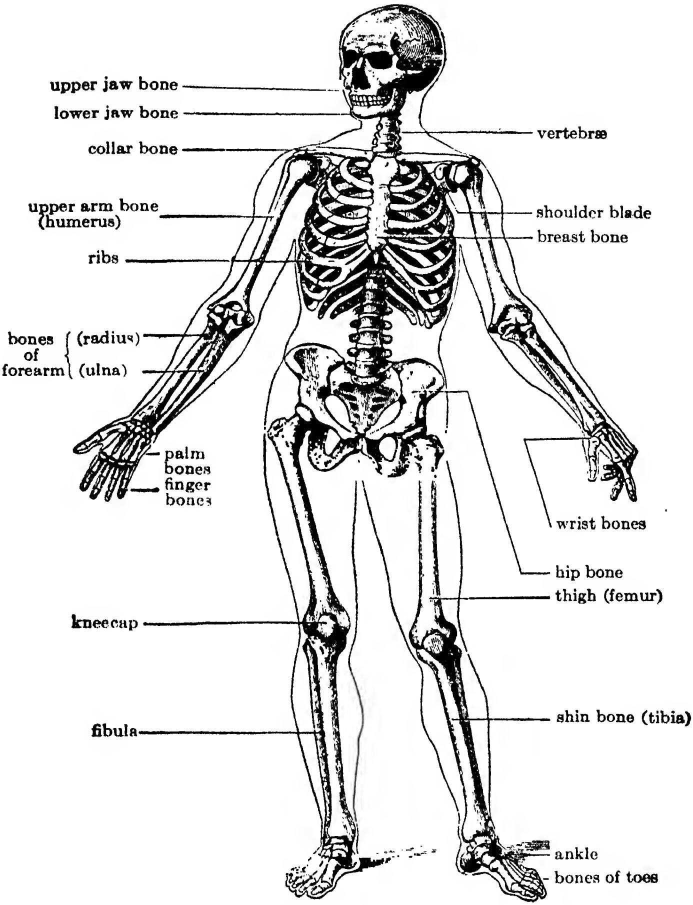


FIG. 44.—Skeleton of man.

Attached to the spinal column are twelve pairs of *ribs*, ten pairs of which connect with the *breastbone* and thus help to inclose the chest cavity (Fig. 44). The arms are attached to the rest of the skeleton by a movable girdle of bones consisting of the two *shoulder blades* and the two *collar bones.* A complete and rigid circle of bones is formed at the posterior end of the trunk by the two *pelvic bones*, which are attached dorsally to the spinal column and meet in front. On the outer side of each pelvic bone is a deep socket into which fits the upper end of the thigh bone (Fig. 44).

211. Skeleton of the arm. — The skeleton of the upper arm (see Fig. 44) is formed by a single long bone called the *hu'me-rus*, which extends from the shoulder to the elbow. In the forearm, one can feel through the flesh two separate long bones, of about the same size, lying side by side; the bone on the thumb side of the forearm is the *ra'di-us;* on the little finger side is the *ul'na.* Eight small bones are found in the wrist; and in the palm of the hand and in the fingers are nineteen somewhat elongated bones. All these twenty-seven bones move freely upon each other and thus give the hand a great freedom of movement.

212. Skeleton of the leg. — In the upper part of the leg (see Fig. 44) is a single bone, the *thigh bone* or *fe'mur.* This corresponds in position to the humerus of the arm, but it is longer and stouter than the latter; in fact, it is the longest bone in the body. The skeleton in the calf of the leg consists of two bones (*tib'i-a* and *fib'u-la*) which have a position similar to that of the radius and ulna. The tibia is on the inner or great-toe side and is much larger than the slender fibula. At the knee joint one can feel a flat piece of bone, more or less circular in outline, called the *kneecap.* The twenty-six bones of the ankle and foot are in the form of an arch, one end of which rests upon the heel.

213. Skeleton of the head. — Two groups of bones may be distinguished in the *skull* or skeleton of the head; namely, the bones forming the *cranium*, which surrounds and protects the brain, and the bones that form the *skeleton of the face* (Fig. 44).

By its rounded contour, the skull furnishes the best possible protection for the brain. In the first place, if a blow strikes upon the head, it would be much more likely to glance off than would be the case if the sides and top were flat.

Since the end of the nose and the outside ear are the most exposed portions of the head, they would, if made of bone, be in constant danger of getting broken. Cartilage, however, gives them sufficient permanence of form, and at the same time this elastic material, if bent out of shape, at once returns to its original position as soon as the pressure is removed.

The deep eye sockets seldom allow any blow to injure the eye. The drum of the ear, the three tiny bones of the middle ear, and the delicate mechanism of the inner ear are all buried deep in the hardest part of the skull, and so these are out of danger.

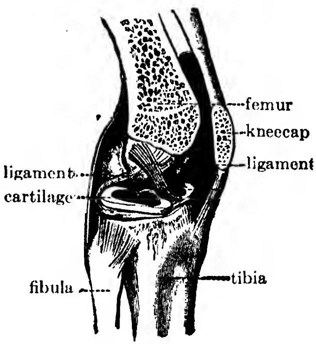


FIG. 45. — Knee joint.

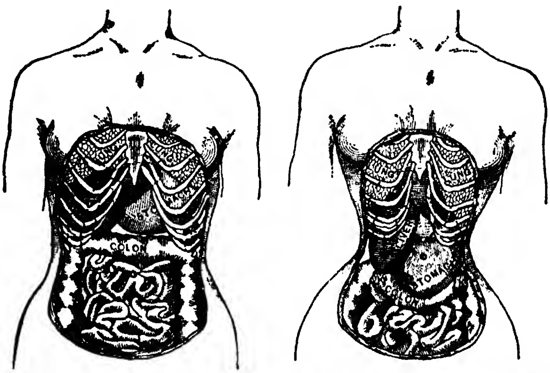
214. Joints. — Thus far we have considered the bones of the skeleton as though they were independent of each other. In the living body, however, we know that they are firmly attached to one another by ligaments and muscles, and that thus a strong but movable framework is formed (Fig. 45). *Any region in the skeleton where motion is possible between two bones is called a joint.*

215. Food and the skeleton. — In the composition of bones, mineral is found to constitute about two thirds of the material, and this must be supplied by the food.

Milk is a most important article of diet in early life, since in addition to the other nutrients, it supplies the phosphate of lime needed for bone manufacture. In the process of refining wheat flour much of the mineral matter is lost; for this reason whole wheat flour and the coarser cereals like corn, rye, and oats are much more valuable as bone builders, and are especially needful during the period of

growth. The mineral matters in our foods are made soluble and are then supplied by the blood to the bone cells, and these in turn convert this mineral matter into the hard intercellular substance.

216. Effect of pressure on bones. — Tight-fitting clothing is a most important factor in modifying permanently the shape and position of bones. Normal growth cannot be attained if the skeleton is subjected to pressure. Yet this important principle of hygiene is constantly violated by women who wear tight-fitting clothing about



A = Normal position of organs. *B* = Position of organs after lacing.

FIG. 46.—Effect of tight lacing on the organs of the chest and abdomen.

the waist. Baneful fashion is often followed even in youth, when the skeleton yields readily to pressure. The result is that the ribs are permanently bent downward and inward, thus interfering seriously with the action of the abdominal organs (Fig. 46). High-heeled shoes are another frequent cause of deformity. They reduce the spring in the arch of the foot and throw too much of the weight of the body upon the tips of the toes, and this is likely to injure the arch of the foot. Shoes with narrow toes should never be worn, since by this means the foot is deformed.

217. Fractures. — Any sudden strain or blow upon a bone is liable to cause a break or a *fracture*, especially in later life, when the

bones are brittle. Fractures occur more commonly in the shafts of long bones, and they may usually be recognized by the fact that an extra joint is thus formed and by the fact that the broken ends grate against each other.

In treating a fracture, the pieces of bone must be brought back into position (this is called "setting" the bone), and must be held in place by splints until the ends have become firmly "knit" together. The setting of a bone should only be attempted by a surgeon. In general but two rules should be followed in case of a fracture: *first, send for a doctor; second, keep the broken bone perfectly quiet in as comfortable a position as possible.* Hot or cold water applications if applied at once often reduce the pain and prevent inflammation. Movement at the point of fracture almost always causes inflammation, which makes the setting difficult; and if moved suddenly, the surrounding tissues may be injured as well.

218. Dislocations. — A *dislocation* is an accident to a joint in which the ends of the bones are forced apart. One can usually recognize a dislocation by the unwonted protrusion of the bones, and by the pain caused when any motion at the joint is attempted. Since ligaments of connective tissue bind the bones together rather closely, a dislocation often results in a wrenching or tearing of the connective tissue about a joint; swelling and discoloration follow quickly; and it is therefore necessary to put the bones back into place, or, in other words, to "reduce the dislocation" as soon as possible. If surgical aid can be procured, it is better to apply cold water to the joint and wait for the doctor's arrival, since by unskillful treatment further injury to the joint may result. When skilled treatment is impossible, most dislocations may be reduced by steadily pulling the bones apart until it is possible for the ends to glide back into place.

219. Sprains. — When a sudden strain causes neither a fracture nor a dislocation, it often gives rise to a twisting or tearing of ligaments and other connective tissues in the region of a joint. Such an accident is called a *sprain.* The injured region is usually swollen and painful. Since it is difficult to distinguish a sprain from other

accidents to the skeleton, medical assistance should be summoned and the following directions carefully followed: (1) the sprained member should be placed at once in cold water or in hot water and held there for some time; (2) arnica or witch hazel may be applied; (3) the sprain should then be bound in a tight bandage (these three applications tend to keep down the swelling); and (4) (most important of all) the joint should have *complete rest* until all swelling and soreness have disappeared. It is probable that more permanent injuries result from careless treatment of sprains than from all other accidents to the skeleton.

III. The Muscles

220. Importance of muscle tissue. — Muscle tissue constitutes 41 per cent, or almost half, of the weight of the human body. In this kind of tissue is found one fourth of all the blood. But the importance of muscle tissue is appreciated, even more fully, when we realize that practically every kind of movement in the body is due to the action of the muscles. Not only do they bring about the more obvious motions of the arms (Fig. 47), the legs, the trunk, and the head, but also the contractions of the heart, of the stomach, and of the other internal organs. Every change in the expression of the face, and every variation in the tone of the voice, is likewise a result of the action of this all-important tissue. Hence we are not surprised that there are *over five hundred separate muscles*, which vary in length from the fraction of an inch (within the ear cavity) to over a foot and a half (down the front of the thigh).

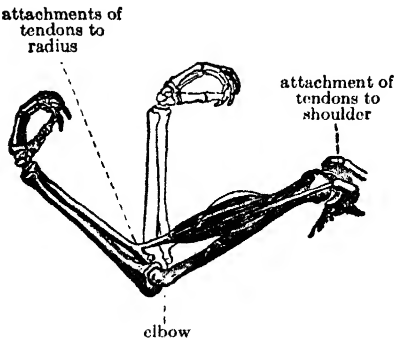


Fig. 47. — Action of biceps muscle.

221. Kinds of muscle. — All of these muscles are in one way or another under the control of the nervous system. Some of them are

directed by the conscious portions of our brain. Thus we can close our fingers and open them as we please; we can move the eyes, the head, and the legs at will. We call all the muscles that are controlled by our will power, *vol'un-ta-ry muscles* (Latin, *voluntas* = will). Most of the muscles of the throat, those of the gullet, stomach, and intestines, on the other hand, act without any voluntary direction on our part, and they are therefore called *in-vol'un-ta-ry*.

222. Conditions necessary for healthy muscles. — If one is to have a well-developed and healthy muscular system, four conditions must be fulfilled: *the body must be supplied with nutritious food; there must be a generous amount of fresh air; the muscles must be exercised vigorously; and this exercise must be followed by periods of rest.* We will now consider in turn how each of these requirements may be met.

223. Food. — We have learned that 75 per cent of muscle is composed of water, and that protein is the most important solid ingredient. Mineral matter and fats are also present in small quantities, even in the leanest of muscle. During the period of growth all these nutrients should be supplied for muscle building, but protein is absolutely essential. Grape sugar is also found to be an important food during muscular contraction. The diet of athletes while they are training for contests is carefully regulated: rare meats, coarse breads, eggs, vegetables, and fruits are supplied in generous quantities; pastry and fats are reduced to a minimum. Tobacco and alcohol in any form, however, are absolutely prohibited. Such a diet is undoubtedly far more wholesome to develop a healthy boy or girl, man or woman, than are the rich gravies, pastries, and condiments which are found on too many tables.

224. Fresh air. — Healthy muscle is absolutely powerless, however, unless, in addition to food, it receives a supply of oxygen; for all muscular energy is produced by oxidation. Impure air, besides being deficient in oxygen, contains carbon dioxid and other gases that are exceedingly harmful to the tissues (**196**). Well-ventilated sleeping rooms are most essential for healthy living, for

during the night the body gets rid of much of the waste carbon dioxid that is formed during the day.

225. Exercise. — It seems like a contradiction to say that the only way to get more and better muscle is to destroy what we already have. Every one knows, however, that if the muscles of the arm or the leg are not used for a time, they become weak and flabby, and yet every time a muscle is made to contract, some of its substance is oxidized. New muscle, formed by the process of assimilation, must take its place.

A certain amount of vigorous exercise each day is essential if one's body is to be kept in the best physical condition. This amount, of course, varies with the individual, and it should never be carried to an excess, resulting in exhaustion. Fortunate is the boy who can spend the early years of his life in the country, and who has been taught to do a certain amount of manual work each day out of doors. Regularity in exercise is as important as regularity in eating. One cannot exercise vigorously one day and expect its good effects to last for a week. We should not call upon the muscles for violent exertion immediately after rising and before breakfast, nor should we exercise until at least a half hour after eating. The physiological reasons for these directions have already been given in our study of the circulatory system (**170**).

The best forms of exercise are those that call into play the greatest number of muscles. For this reason gymnasium training is better than many kinds of outdoor sports. In the gymnasium, too, special forms of exercise may be taken to develop any muscles found to be weak. On the other hand, lawn tennis, golf, rowing, and football have the additional advantage of being played in the open air, and games of this sort are usually more exhilarating than are set forms of exercise with apparatus. That the full effect of any kind of exercise may be attained, it should be followed by a moderately warm, then by a cold, shower, or sponge bath, and by a good rubbing of the body with a coarse towel.

Muscles are not the only tissues developed by exercise. Every muscular contraction is directed by some kind of stimulus from the

nervous system. Before the muscles of the arm or leg contract, a " message " must come to them from the brain or spinal cord; hence nerve tissue is likewise developed by exercise.

226. Rest. — If physical exertion is carried beyond a certain point, exhaustion results, and the muscles cannot be made to contract until after a period of rest. Since all muscular contraction involves oxidation of tissue, periods of rest must be allowed for the muscles to get rid of their wastes and to build up new tissue in place of the old. The feeling of weariness after long-continued exercise is probably due to the presence in the body of great quantites of carbon dioxid, water, and other wastes. One can often rest to good advantage by changing from one form of activity to another, but from eight to nine hours of sound sleep each night are indispensable for the health of a growing youth. The necessity for sleep will be further discussed in the study of the nervous system.

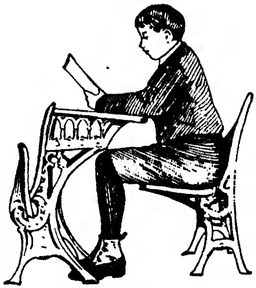
A = Correct posture. *B* = Incorrect posture.

FIG. 48. — Standing positions.

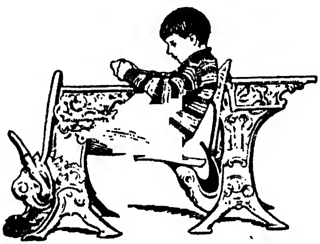
227. Relation of muscles to proper posture. — An erect posture and graceful carriage not only add to pleasing appearance, but are important in maintaining the health. Round shoulders and stooping position decrease the capacity of the chest and interfere seriously with the action of its organs. It is important that boys and girls acquire a good posture early in life, and that they realize that *this*

is largely a matter of muscular training. In standing (Fig. 48), the head and body should be erect, the heels brought close together, and the shoulders brought into such a position that the back is approximately flat. In sitting (Fig. 49), care should be taken not to bend the body over the desk, and a proper relation between height of chair and desk should be secured.

Permanent curvature of the spine frequently results from carrying loads of books or other heavy objects on one side of the body only; pupils should therefore train themselves to use the arms alternately for this purpose.



A = Correct posture.



B = Incorrect posture.

C = Desk and seat too low.

Fig. 49. — Sitting positions.

IV. The Nervous System

228. The body as a collection of organs. — In the preceding chapters we have discussed the digestive, respiratory, and circulatory systems and have seen that these organs furnish all parts of the body with food and oxygen. We have studied the process of oxidation whereby we keep warm and gain the power to do work. And finally we are familiar with the fact that the bones and muscles are the organs that give support to the body and provide the machinery for all our motions. Thus we see that the body is composed of many organs, each with its special function or functions.

229. Coöperation of the organs. — But a human being is more than a mere collection of working organs, for *all the various organs work together for the common good.* This is what we mean by *coöperation* (Latin, *co* = together + *operari* = to work). Suppose we take a few instances from everyday experience to illustrate this coöperation.

When food is taken into the mouth, the salivary glands pour out upon it an abundant supply of saliva. Now, the food never comes in contact with the glands. How is it, then, that they send out their secretion at just the right time and in the proper amount?

If a blow is aimed at one's face, one's hands immediately fly up to ward off the threatened injury. If the attack were pressed and one were really compelled to defend himself, his heart would beat much more rapidly, he would breathe faster, and the flow of perspiration would become evident. During the contest certain feelings, also, would doubtless be aroused.

230. Functions of the nervous system. — All the succession of activities just described would be utterly impossible if some means were not provided for making the organs work together for the common good. The arms could not see to strike at the antagonist; nor could the heart, lungs, or skin respond to the sudden exertion of the rest of the body. It is the nervous system that controls the action of each of the organs in the body and brings about a coöperation between them. All our sensations, too, and our will power are doubtless correlated with the activities of the nervous system.

231. Parts of the nervous system. — The nervous system consists of *nerve centers* and *nerve fibers* (of which *nerves* are composed). The principal nerve centers are the *brain* and *spinal cord* (Fig. 50). These delicate organs are inclosed and wonderfully protected by the bony cranium and spinal column.

From the brain and spinal cord pass off numerous *bundles of nerves*. As they approach the different organs of the body they divide into branches, and thus the nerves become smaller and smaller. Finally, the microscope is needed to trace the individual nerve fibers to their endings in muscle, gland, or sense organ. By

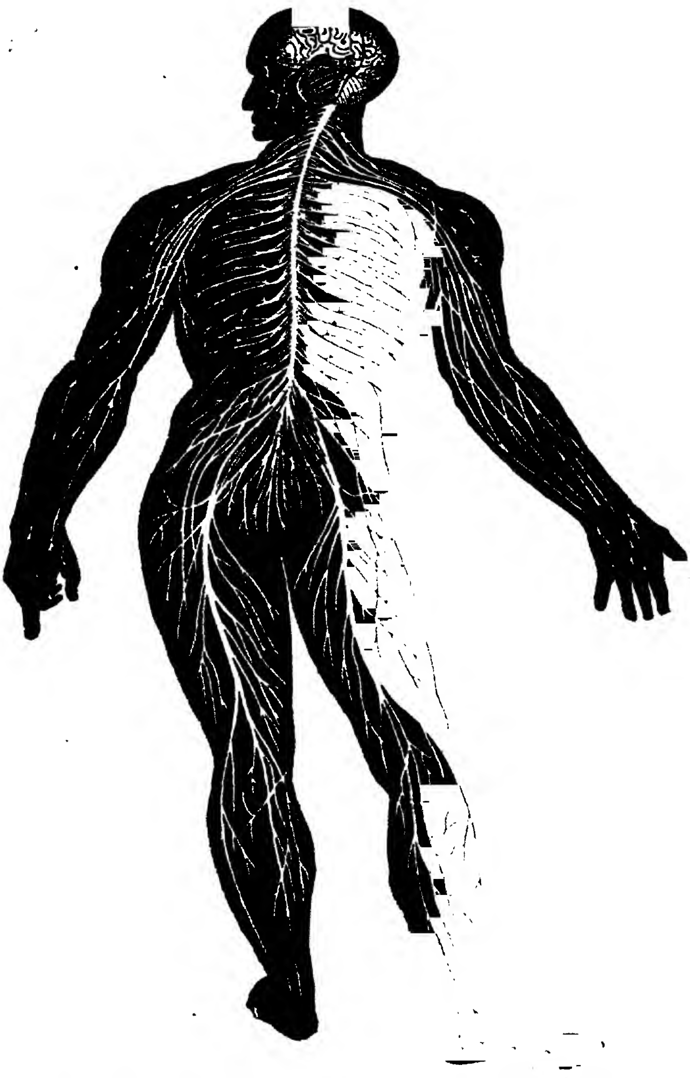


FIG. 50. — General arrangement of nervous system.

means of these countless nerve fibers all parts of the body are put in communication with the nerve centers (see Fig. 50).

232. Cellular structure of the nervous system. — If a section is made of any part of the brain or spinal cord, two kinds of material, known respectively as *gray matter* and *white matter*, may be distinguished. In the gray matter are countless *nerve cells* (Fig. 51) which are very irregular in form. From most of the nerve cells project numerous fine processes that look like tiny branching roots. These bring the various nerve cells into communication with each other.

One fiber-like process, however, has fewer branches than the others, and may be traced for a considerable distance from the cell body. This is the beginning of a nerve fiber, and it is the mass of nerve fibers that make up most of the white matter of the nervous system.

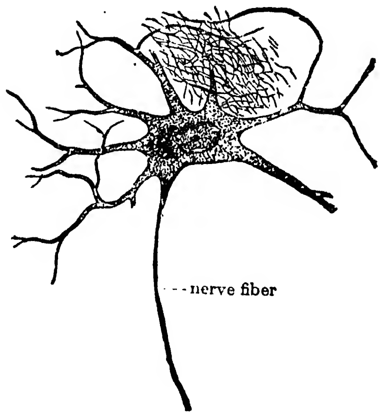


FIG. 51. — Nerve cell from spinal cord.

233. Nerve impulses. — We may compare nerve fibers to telegraph wires, and nerve impulses may be described as messages that pass along these fibers. But in making these comparisons we must remember that *telegraphy and the action of the nervous system have, in all probability, little real resemblance.* We know that nerves transmit impulses at the rate of about one hundred feet per second; electricity travels thousands of miles per second. Hence a nerve impulse cannot very closely resemble what we call a telegraph message. On the other hand, this nerve impulse travels much too rapidly to be explained as a chemical or mechanical action. We must therefore admit our ignorance of the real nature of the nervous impulse; nor do we know the real nature of the changes that take place in the nerve cells after receiv-

ing the so-called message. The principal functions of the brain may for convenience be divided into (1) reflex activities, (2) conscious activities, and (3) automatic activities or habits.

234. Reflex activities. — To illustrate the reflex action of the brain suppose we inhale some pepper; a message goes up the nerves to the cells in the nerve centers. This message is then reflected or switched off to cells which send impulses down the nerves that control the muscles of the chest. We then sneeze, and thus get rid of the pepper. Coughing, winking, blushing, the flow of saliva at the sight of savory food, — these are but a few of the reflex activites carried on by the brain.

235. Conscious activities. — As long as we keep awake, countless nerve impulses keep pouring into our brains. When the cells of the gray matter receive these impressions, we usually become conscious that we are seeing, smelling, hearing, tasting, or feeling. These sensations are more or less lasting, too, for we can recall distinctly the appearance of objects that we saw yesterday, or even years ago, and we can hear again, as it were, the sounds we have heard in the past. In some unknown way these impressions are stored away in the protoplasm of the brain, and constitute our *memory*.

Another power of which we are conscious is the ability to direct the movements of the body. We can rise from a seat, walk about, talk or change the expression of our faces as we will.

236. Habitual activities. — If we can remember the time when we learned to write, we recall that each letter was traced laboriously by a conscious effort of our brains to guide the muscles of our fingers. Writing, in our early years, belonged to the group of our conscious activities. But as time went on, less and less of our attention was needed for this mechanical process, until now our fingers seem to move of themselves. Walking, bicycle riding, swimming, playing the piano, conveying the food to our mouths — none of these activities require our attention. We have made these movements so many times that they have become *automatic*. In other words, the conscious part of our brains has trained other nerve centers to

direct many of our everyday doings. Our attention is thus set free to carry on other kinds of work.

"As every one knows, it takes a soldier a long time to learn his drill — for instance, to put himself into the attitude of 'attention' at the instant the word of command is heard. But, after a time, the sound of the word gives rise to the act, whether the soldier be thinking of it, or not. There is a story, which is credible enough though it may not be true, of a practical joker, who, seeing a discharged veteran carrying home his dinner, suddenly called out 'Attention!' whereupon the man instantly brought his hands down, and lost his mutton and potatoes in the gutter. The drill had been thorough, and its effect had become embodied in the man's nervous structure."[1]

237. Importance of habit. — The tremendous importance of making our habits our allies instead of our enemies cannot be emphasized too strongly.

"The hell to be endured hereafter," says Professor James, "of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but it is being counted, none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral,

[1] Huxley's "Lessons in Elementary Physiology," Macmillan Company.

however, he may still be able to ride (on horseback), and a man who is so drunk that he cannot walk and cannot speak may ride perfectly well. . . . Later on the further anæsthetic action of the alcohol abolishes sensation, and its paralyzing action destroys the power of the spinal cord, so that the man is no longer able even to ride; but still the respiratory center in the medulla will go on acting, and it is not until enormous doses of alcohol have been given that respiration becomes paralyzed.

"Alcohol . . . makes all the nervous processes slower, but at the same time it has the curious effect of producing a kind of mental anæsthesia, . . . so that these processes seem to the person himself to be all quicker than usual, instead of being, as they really are, much slower. Thus a man, while doing things much more slowly than before, is under the impression that he is doing things very much more quickly. What applies to these very simple processes applies also to the higher processes of the mind; and a celebrated author once told me that if he wrote under the influence of a small quantity of alcohol, he seemed to himself to write very fluently and to write very well, but when he came to examine what he had written next day, after the effect of the alcohol had passed off, he found that it would not stand criticism." [1]

V. The Eyes

243. Protection for the eye. — The delicate organs of vision, the eyes, are protected in a wonderful manner. In the first place, the eyeballs are set far back in bony sockets, in such a way that, even if one falls forward or if the face is struck with a large object, there is little danger that the eyes themselves will be hit. Again, each eyeball is covered by two movable lids that involuntarily close at any threatened danger. And, finally, the curving eyelashes on the edge of each lid protect the eyeball to a considerable extent from dust and dirt.

244. Structure of the eye. — Each eye is nearly spherical in shape (Fig. 52). Its outer surface is covered with a tough coat which

[1] T. Lauder Brunton, London, "Lectures on the Action of Medicine," pp. 190, 191, 194.

is white in color, except in front, where it becomes the transparent *cornea.*

Inside of the outer coat is a second layer which is seen beneath the cornea as a colored ring known as the *iris.* In the center of the iris is a circular opening, the *pupil,* which is black in appearance. Through the pupil enter the rays of light into the interior of the eyeball. If one comes suddenly from a dark room into the light, it is possible to see this opening quickly decrease in size. The inner lining of the eyeball is extremely thin and black in color; it is known as the *retina,* and connected with it are the many nerve fibers that carry messages to the brain.

Behind the iris is a beautiful transparent object, *the crystalline lens,* both surfaces of which are convex. The space within the eyeball in front of this lens is occupied by a liquid, and behind the lens is a jellylike substance.

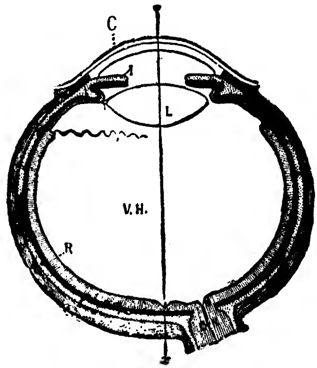


FIG. 52. — Section of the eye.

C = Cornea.
I = Iris.
L = Crystalline lens.
ON = Optic nerve.
R = Retina.
$V. H.$ = Jellylike substance.

245. The eye as a camera. — Any one who is at all familiar with a camera knows that by means of a lens, or a combination of lenses, the scene to be photographed is made to appear upside down on the ground glass plate at the back of the camera. If the image is not clear, it is brought into focus by moving the lens nearer to, or farther from, the object.

In the eye, too, we have an arrangement similar to that of a camera, since the convex surfaces of the cornea and crystalline lens (Fig. 53) focus the rays of light so that an image is formed on the sensitive retina at the back of the eye. Since, however, the lenses within the eye cannot be moved backwards and forwards, as in a camera, focusing or *accommodation* of the eye must be accomplished

in a different way, namely, by making the elastic lens more or less convex.

246. Sensations of sight. — We shall now try to see how it is that the eye helps us to get sensations of sight. If an object, say an arrow, is held in front of the eye, rays of light pass in a great many directions from every part of the arrow tip. A considerable number of these rays strike the convex surface of the cornea and the crystalline lens, and are thereby *focused*, or made to converge upon a point on the retina. In the same way the light rays from every other part of the arrow are brought to focus on the inner surface of the retina. By this means a *smaller, inverted image*, of the arrow (Fig. 53) is

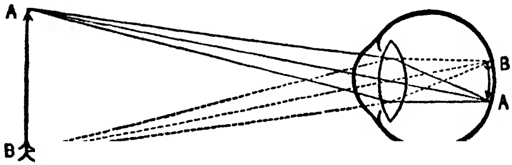


Fig. 53. — Formation of an image on the retina.

projected on the inner lining of the eye. The influence of these light rays then passes through the layers of the retina, and when these so-called " messages " traverse the nerve fibers and reach the brain, we become conscious of sensations of sight.

247. Defective eyes. — A normal, healthy eye has the power of adjusting itself so that objects become visible which are within five to ten inches, or as far away as a distant horizon. Many people, however, find that they can see objects near at hand much more clearly than those at a distance; in other words, they are *nearsighted*. Others, on the other hard, are *farsighted*. These defects in vision are due to imperfect formation of the eye, and can be corrected only by the use of proper *eyeglasses or spectacles, which should be purchased only on the recommendation of a competent eye specialist*.

Another very common defect of the eye is known as *a-stig'-ma-tism*. Many people, on looking with each eye separately at

Figure 54, find that some of the radiating lines stand out sharply defined, while others are indistinct or blurred. In reality, all the lines are equally distant from each other, and the indistinctness referred to above is due to the fact that some of the rays of light are not brought to a focus. Astigmatism, like nearsightedness and far-sightedness, should be corrected by the use of proper glasses, otherwise constant eyestrain is likely to cause headaches and other disorders of the body.

Some people, too, are unable to distinguish clearly various colors; thus, red and green may appear the same to them. In other words, such people are *color blind*. Color blindness cannot be corrected by glasses, but may be to some extent by training.

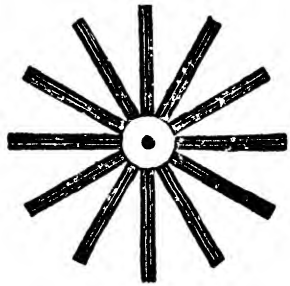


FIG. 54. — Test for astigmatism.

248. Hygiene of the eyes. — The eyes have, as we know, wonderful powers of adapting themselves to varying conditions. This adaptability often leads us to abuse them. Thus, we frequently read when the light is insufficient, we look steadily at objects until we suddenly find that we cannot see clearly, and we read or study while riding in swiftly moving trains. In these and other ways we compel our eyes to make adjustments under trying conditions, and more or less eyestrain is sure to follow.

When we read, we should make sure that the light is sufficient, that it is steady, and that it comes over the left shoulder. The type on the printed page should be little, if any, smaller than that in which most of this book is printed, the lines should not be close together, and the paper should not have a glossy surface to reflect the light into the eyes. One should remember, too, that the eyes, like other organs of the body, need frequent periods of rest. Hence study hours should be followed by periods in which the eyes are allowed to relax. Pupils who have defective eyesight should at once secure proper glasses.

VI. The Ear

249. The external ear. — Attached to each side of the head is an oval, more or less flattened expansion, composed largely of cartilage and connective tissue. The irregular surface of this outer portion of the ear doubtless helps somewhat, like an ear trumpet, to catch and converge the sound waves into the funnel-like canal which is about an inch long, and leads to the interior of the head.

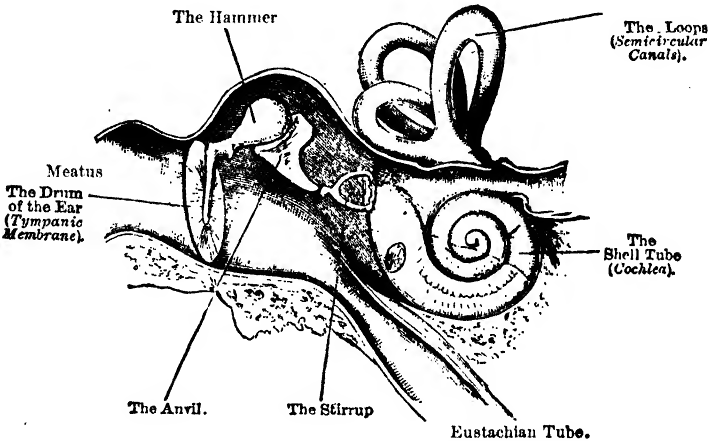


Fig. 55. — Middle and inner ear, greatly enlarged.

In the lining of this canal are certain *wax glands;* these secrete a thin fluid which, on thickening, hardens into a yellow paste, the *earwax.* Across the inner end of this tube of the external ear is stretched a thin membranous partition, known as the *eardrum,* or *tym'pa-num* (Latin *tympanum* = drum (Fig. 55)).

It is never safe for one to thrust into the canal of the ear any hard object, because of the danger of puncturing the eardrum. Ordinarily the canal cleans itself, but if it is necessary to remove bits of wax or dirt, this should be done with a tightly rolled corner of a piece of cloth. It is dangerous, too, to punish a child by boxing the ears,

because the sudden compression of the air is likely to injure the drum. Earache is often relieved by hot applications; never should laudanum or other substances be put into the ear without the advice of a physician.

250. The middle ear. — Beyond the tympanum is a small cavity, known as the *middle ear.* From this cavity a narrow tube (the *Eustachian tube*) about an inch and a half long, communicates with the upper part of the throat cavity (Fig. 55). If one were to go up on a high mountain, he would find that the pressure of the air on the outside of the body, and therefore on the exterior of the eardrum, would become less, and if some of the air in the middle ear were not to escape, the eardrums would be forced outward, and hence would be ruptured. If, on the other hand, one should go into a deep mine, the increased pressure on the outside of the drums would force them inward. All these accidents are prevented by the presence of the Eustachian tubes, through which air can pass into and out from the middle ear, and so the pressure on both sides of the tympanum can be equalized. In severe head colds, the opening from the throat cavity into the Eustachian tubes becomes temporarily closed and we are then conscious of a ringing sensation in the ears. Catarrh sometimes closes the Eustachian openings and causes deafness. If the hearing seems to be at fault in any way, a specialist should be consulted.

251. Sensations of sound. — When a stone is dropped into water, the ripples move outward over the surface in circular waves. In a similar manner sound waves are transmitted in all directions from a given body, for instance, a vibrating bell. When some of these sound waves enter the tube of the external ear, they cause the eardrum to vibrate, and this vibration is transmitted across the middle ear by a chain of tiny bones, and so reaches the complicated inner ear, which is a series of canals imbedded in solid bone. The inner ear contains a large number of sensitive cells which transfer the vibrations to nerves communicating with the brain. When the brain cells receive and interpret these impulses, we get sensations of sound.

GREAT BIOLOGISTS

252. Library studies of biologists. — Select for study one or more of the following men who have made great contributions to our knowledge of biology: Agassiz, Aristotle, Audubon, Darwin, Harvey, Huxley, Jenner, Koch, Lamarck, Leeuwenhoek, Linnæus, Lister, Pasteur, Spencer, Wallace. Consult Locy's "Biology and its Makers," Williams's "A History of Science," Encyclopedias or other works of reference as to (1) the important events in the life of the biologist, and (2) his contributions to biological science.

Louis Pasteur [1] (See Frontispiece)

I. Interesting Features of his Biography.

1. *Parents.*
   - *a.* Father (Jean Joseph), a tanner — sergeant major in Napoleon's army — decorated with Legion of Honor.
   - *b.* Mother (Jeanne Rogui) of middle class family.
2. *Birth,* at Dôle (in Eastern France), Dec. 27, 1822.
3. *Education.*
   - *a.* In colleges near his birthplace (Arbois and Besançon) — early evidences of remarkable ability in concentrating his mind in study.
   - *b.* In colleges at Paris — much influenced by the scientists Dumas and Biot.

[1] The ability to prepare *logical outlines* of library or laboratory studies is of great value to students (1) because in this form the principal facts can be stated more briefly than is possible in continuous paragraphs, and (2) because the various interrelations of the facts may be more clearly shown. In preparing such outlines the student should first select the most important division topics, all of which should be of equal value and expressed in similar form. Each of the various subordinate topics should be an organic part of the main division topic under which it is placed; each should be stated in a brief form, and as far as possible words or phrases should be used and verbs, clauses, or sentences avoided.

The outline on the life and works of Louis Pasteur is inserted (1) because of the importance of Pasteur's work, and (2) as a suggestive form for biology records.

4. *Professional work.*
   a. Professor of Physics at Dijon (1848), and of Chemistry at Strassburg (1849).
   b. Professor and Dean of Faculty at Lille (1854).
   c. Scientific Director of Ecole Normale, Paris (1847), and Professor of Chemistry at Sorbonne, Paris (1867).
   d. Director of Pasteur Institute, Paris (1888).
5. *Death*, at St. Cloud, Sept. 28, 1895.
6. *Position as a scientist.*
   a. His life devoted to most important scientific investigations.
   b. Highest honors bestowed upon him by men of science in all countries.
   c. "The most perfect man in the realm of science."

II. Important Contributions to Biological Knowledge.

1. *Investigations relative to fermentation and decay.*
   a. Fermentation formerly believed to be purely a chemical process, independent of the activity of living organisms.
   b. Fermentation and putrefaction proved by Pasteur to be always due to the action of living microörganisms (yeast and bacteria).
   c. Each kind of fermentation or decay demonstrated to be due to the activity of different kinds of germs.
2. *Discoveries relative to silkworm disease.*
   a. Silk cultivation throughout France and Italy threatened by this disease.
   b. Silkworm disease proved by long investigations of Pasteur to be due to minute germs infesting eggs, larvæ, pupæ, and moth of silkworm.
   c. Disease eradicated by scientific treatment suggested by Pasteur.
3. *Researches relative to splenic fever among horses, cattle, sheep, and human beings.*
   a. Rod-shaped bacteria found to be the cause of the disease.
   b. Bacteria from the bodies of buried victims of the disease

proved by Pasteur to be brought to the surface by earthworms.

c. Splenic fever checked by inoculating animals with a virus prepared in a manner somewhat like that of the virus of hydrophobia (see 4 below).

4. *Discoveries relating to hydrophobia (1885).*

a. Hydrophobia demonstrated to be a disease attacking the nervous system of victims bitten by mad dogs, wolves, or cats.

b. Solutions made from fresh spinal cords of animals thus bitten, on being injected into healthy animals always cause hydrophobia.

c. Spinal cords of animals dying of hydrophobia found to lose virulence (*i.e.* disease-producing power) after being dried.

d. Virus (*i.e.* glycerine solutions) obtained from spinal cords dried for varying lengths of time found to contain corresponding degrees of virulence.

e. Method of treatment for hydrophobia.

(*a*) Cauterization (burning) of wound with strong nitric acid.

(*b*) Injection on twenty-one successive days of virus of gradually increasing strength.

f. Result of Pasteur treatment in Paris; of 21,631 cases treated only 99 victims of the disease died, *i.e.* less than 1 per cent.

5. *Discoveries of other scientists directly due to Pasteur's work.*

a. Lister's methods of antiseptic treatment of wounds.

b. Koch's investigations as to the cause and treatment of tuberculosis.

c. Roux's and von Behring's antitoxin treatment for diphtheria.

APPENDIX I

LABORATORY EQUIPMENT

The laboratory. — It is very desirable that a definite room or rooms be set apart for work in biology, since at least a minimum equipment is essential, and this cannot be transferred from room to room without considerable loss of efficiency. While it is desirable to have tables or at least flat-topped desks of good size, satisfactory

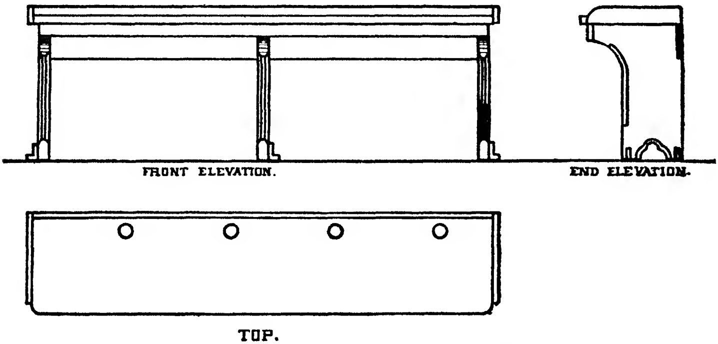


FIG. 87. — Plans for a laboratory table.

laboratory work can be done in an ordinary class room if it is well lighted. The laboratory should be supplied with a demonstration table and gas connection if possible, with sink and running water, and a broad shelf should be placed in front of the windows for supporting growing plants and aquaria, and for use in demonstrations with the compound microscope. Ample closet room should be provided in which to store apparatus and supplies, so that they may be kept free from dust.

In case it is possible to equip a room with laboratory tables the following type is suggested. In the first place the laboratory tables should be firmly fixed to the floor, and arranged so that the light comes from the left side, and if possible also from the back of the room. The desk tops should be 30 inches from the floor and 20 inches wide, and should be made of maple or other hard wood. The length of each table will of course depend upon the dimensions of the room, but if possible no more than three pupils should be provided for at a single table. Each student should have at least 30 inches of the table space. (Fig. 87.)

" The finish of the laboratory table tops is a matter of importance, since it must be such as to protect the wood from damage, and keep it clean and smooth. Many prefer a black finish, to obtain which the following method gives good results.

"Make up solutions:

(1)	Copper sulphate ($CuSO_4$) . . .	625 grams
	Potassium chlorate ($KClO$) . . .	625 grams
	Water to make	5 liters
(2)	Anilin oil	300 grams
	Hydrochloric acid (HCl)	450 grams
	Water to make	5 liters

" Apply solution (1), followed immediately by (2) several times, until the wood becomes a dark green, allowing the applications to dry each time. The darker the tone reached, the better. The wood must then be washed thoroughly with soap and hot water applied with a brush. This is necessary in order to remove the superfluous salts. The table is finished with oil and will then be dead black."[1]

The advantages of the dull black finish are these: (1) there is little reflection of light from this kind of surface into the eyes of the pupils; (2) the black surface furnishes an admirable background for many objects of study; and (3) the tops are not injured by water, acids, or other chemicals.

Experience has shown that unless the laboratory must be used

[1] From Lloyd and Bigelow's "The Teaching of Biology."

as an assembly room for a division at the beginning and close of school, drawers and shelves beneath the desk are of little real use, and often become mere receptacles for laboratory débris, unless they are provided with locks. It is usually far safer and more satisfactory to collect drawings, magnifiers, pencils, etc., at the close of the period, and to distribute materials as they are needed during the next period. If this work is properly systematized and the assistance of pupils is made use of, very little of the laboratory time is lost in this way.

Seats fixed to the floor, likewise, are of great advantage. The authors have found that the best seat for this purpose is the Chandler chair, which is furnished by the American Seating Company, 19 West 18th St., New York City. It has a strong iron base, which can be screwed to the floor, and the chair seat turns on ball-bearings through an arc of 180 degrees. The price of the chair is $2.

Apparatus and chemicals. — The following lists of apparatus and chemicals are suggested as a minimum equipment for a class of 24. Most of the items can be purchased from any one of the following dealers:

Bausch and Lomb Optical Co., Rochester, New York.
Kny-Scheerer Co., 404 West 27th St., New York City.
O. T. Louis, 59 Fifth Avenue, New York City.

QUANTITY	APPARATUS AND GLASSWARE	ESTIMATED PRICE
1	Compound microscope, with $\frac{2}{3}$- and $\frac{1}{6}$-inch objectives, double nose-piece, 1 inch eye-piece, and revolving disk-diaphragm	$30.00
24	Magnifiers, doublets, $1\frac{1}{2}$-inch focus	16.20
1	Harvard trip-scale balance	6.00
12	Evaporating dishes, 3 inches diameter	1.50
1	2-quart agate double boiler	1.50
2	Alcohol lamps *or*	.50
2	Bunsen burners (if gas is available)	.40
3 ft.	Rubber tubing (heavy) to fit Bunsen burners	.60
144	Slides, plain, 1 × 3 inches	.80

1 oz.	Cover glasses (round)	$ .70
12	Sloyd knives	2.25
24	Forceps (heavy)	5.00
12	Dissecting scissors	2.25
50	Handles (adjustable) for dissecting needles	2.00
100	Needles for handles	.25
144	6-inch test tubes	1.50
12	8-inch test tubes, hard glass	1.50
2	Chemical thermometers (Fahrenheit and Centigrade scale on same)	2.00
1	Lactometer	.50
1	Radiometer	1.10
2	Iron ring-stands (3 rings)	1.10
2	Pieces wire gauze (4 × 4 inches)	.08
2	Pieces asbestos (4 × 4 inches)	.07
6	Glass stirring rods	.10
25 ft.	Glass tubing, 5 mm. outside	.30
10 ft.	Rubber tubing to fit glass tubing	.70
12	Thistle tubes (medium size)	1.00
12	Beakers, 150 to 250 cc.	1.50
3	Bell jars 2 feet high and 10 inches in diameter	14.40
3	Bell jars about 8 inches high and 10 inches in diameter	5.00
1	Bell jar, open top, 8 inches high and 8 inches in diameter	2.00
1 piece	Sheet rubber 2 feet square (should be kept in lightning fruit jar when not in use)	1.50
24	Lightning fruit jars (1 quart)	3.00
6	Flasks, 250 cc.	1.00
36	Petri dishes, 4 inches in diameter	6.00
1	Cylindrical graduate, 1000 cc.	1.35
1	Cylindrical graduate, 100 cc.	.40
6	Tall glass cylinders (1000 cc.)	1.75
1	Box slide labels	.10
1	Box labels, 2 × 3 inches	.18
1	Steam sterilizer, copper bottom, 18 inches high	6.00

50	8-ounce wide-mouthed bottles	$2.20
50	4-ounce wide-mouthed bottles	1.60
24	200 cc. narrow-mouthed bottles with ground glass stoppers	2.60
100	Vials with corks, 3 inches high, 1 inch in diameter .	2.75
100	Corks to fit 8-ounce wide-mouthed bottles . . .	1.00
100	Corks to fit 4-ounce wide-mouthed bottles . . .	.75
100	Corks to fit 6-inch test tubes	.40
10	Rubber stoppers with 2 holes to fit 250-cc. flasks . .	.45
10	Rubber stoppers with 1 hole to fit 6-inch test tubes .	.30
2	Insect spreading boards	1.00

Quantity	Charts and Preparations	Estimated Price
11	Jung plant charts (pansy, horse-chestnut, tulip, linden, potato, carrot, pea, Spirogyra, mold, fern, moss)	$13.20
1	Teachers' Botanical Aid, 28 charts, containing 300 drawings (Western Publishing House, Chicago, Ill.)	12.50
11	Jung animal charts (fish (external), fish (internal), frog, Amœba, Paramecium, crayfish, bee, butterfly, cricket, finch, duck)	13.20
4	Leuckhart animal charts (grasshopper, bee, butterfly, metamorphosis of frog)	8.00
1	Model of heart and lungs (dissectible), natural size	12.75
1	Model of digestive system on panel, natural size .	15.75
1	Model of circulatory system on panel, natural size .	11.75
1	Articulated human skeleton, clutch standard . . .	35.00
1	Life history of butterfly	6.00
1	Life history of honey bee	5.00
1	Life history of frog	5.00
1	Life history of fish	5.00
1	Half skeleton of fish (glass case)	3.00
1	Half skeleton of frog (glass case)	4.00

7	Microscopical slides of plant tissue (cross section and longitudinal section of young root, cross section and longitudinal section of stem one year old, cross section of hydrangea leaf, epidermis of leaf, separate wood cells, ducts, conjugating Spirogyra)	$3.50
5	Microscopical slides of animals (Amœba, Paramecium, frog's blood, human blood, mouth parts of bee)	3.00

Quantity	List of Chemicals	Estimated Price
2 lb.	Hydrochloric acid	$1.00
1 lb.	Nitric acid	.28
1 lb.	Ammonia	.26
1 oz.	Iodine	.30
5 oz.	Potassium iodide	.90
1 lb.	Ether	.40
1 lb.	Caustic soda	.30
1	Small tube red litmus paper	.08
1	Small tube blue litmus paper	.08
1 gal.	95 per cent alcohol	3.50
10 lb.	40 per cent formalin	1.70
8 oz.	Glycerin	.25
1 oz.	Pepsin	.30
1 lb.	Peptone	2.00
1 oz.	Taka diastase	1.70
1 lb.	Salt	.05
1 oz.	Phosphate of lime	.12
1 lb.	Grape sugar	.12
½ lb.	Cooking soda	.10
1 lb.	Copper sulphate	.35
1 lb.	Rochelle salt	.30
1 jar	Beef extract	.75
1 lb.	Agar	.90
½ lb.	Powdered sulphur	.07
1 lb.	Potassium chlorate	.20

½ lb.	Manganese dioxid	$.35
1 lb.	Granulated zinc	.25
1 lb.	Absorbent cotton	.35
6	Small candles	.10
1 lb.	Marble pieces	.10
5 lb.	Plaster of Paris	.10
5 oz.	Potassium cyanide	.10
1 oz.	Ferric chloride	.05
1 lb.	Corn starch	.10
½ lb.	Arrow root starch	.15
1 oz.	White egg albumen	.12
1 oz.	Powdered carmine	.40
1 oz.	Gluten	.15

APPENDIX II

BIOLOGY NOTE-BOOK

The following directions for guiding pupils in the preparation of their note-books have been found by the authors to be of great assistance.

1. In the upper right-hand corner of the outside front cover of your note-book write your name, division (*i.e.* grade and section), and the classroom in which you meet at 9 A.M. thus:

   JOHN S. JONES, I–8 (or IA)
   Room 416

   Across the middle of the front cover write BIOLOGY NOTE-BOOK.
2. Cover your note-book with manila paper, and on the front cover put the information called for in 1 above. Be sure to keep your note-book covered.
3. Write your name, division, and classroom in the upper right-hand corner of the first page of your note-book. Leave the rest of this page blank for the teacher's ratings and comments.
4. Number each page of your note-book.
5. On each of the pages draw a vertical line about an inch from the left margin. Always leave this marginal space for the teacher's comments.
6. Begin each new subject on a new page, writing its title on the first line. The first composition or notes should commence on page 5, the preceding pages being reserved for index.
7. Write your compositions or notes in ink on both sides of the page.
8. Indent about an inch the first word of each paragraph. All other lines should begin at the left margin line. It is

suggested that the paragraph titles used in the laboratory studies be employed and that they be underlined (*e.g.* Parts of a Leaf).

9. Make sure that your statements in each paragraph or in your notes are sufficiently full and clear to be readily intelligible to one who knows nothing of the subject.
10. In your compositions or notes be careful to make clear what you yourself *did*, what you *saw*, what you *heard*, and what you *read*. Accounts of experiments may often be written in four paragraphs as follows: object of experiment; preparation of experiment; result of experiment; conclusion from experiment.
11. If, on account of absence, it is necessary that work be copied, inclose such account in quotation marks, and write at the end of such quotation the name of the pupil from whom the account was copied.
12. Every correction indicated by the teacher should be made by the student as soon as the note-book is returned.
13. Every student who wishes to do so can produce a first class note-book, neat in appearance, and at least relatively free from mistakes in spelling, punctuation, and grammar.

Marks used in the Correction of Biology Papers

cp = mistake in use or in omission of capital letter.
cl = meaning not clear.
gr = mistake in grammar.
n = composition is lacking in neatness.
¶ = error in paragraphing.
p = mistake in punctuation.
r = repetition of word or idea.
sp = error in spelling.
w = word improperly used.
? = doubt as to the truth of the statement.
( ) = words in parenthesis are to be crossed out.
∧ = some omission.

APPENDIX III

REVIEW TOPICS IN HUMAN BIOLOGY

The student should be prepared to give a good oral recitation on each of the following topics. If he is not sure of any of the facts called for, he should write down the topic or topics and ask the teacher at the beginning of the next recitation how to obtain the information.

A. The General Structure of the Human Body.

1. *Regions of the human body:* external regions; general plan of internal structure.
2. *Organs of the body:* definition; examples, with functions of each.
3. *Tissues of the body:* examples, with characteristics of each.
4. *Cells of the body:* protoplasm; assimilation, growth, and cell division; cells of mouth; cells of the blood, and of other tissues.

B. Microörganisms and their Relation to Human Welfare.

1. *Bacteria:* microscopical appearance and size; reproduction; spore formation.
2. *Occurrence of bacteria:* proofs of their presence, (*a*) in air, (*b*) in water, milk, and other foods, (*c*) on various parts of the human body; effects of (*a*) different degrees of temperature (including Pasteurization of milk), (*b*) lack of moisture, (*c*) antiseptics.
3. *Bacteria as the friends of man:* relation, (*a*) to soil fertility, (*b*) to flavors of food, (*c*) to linen and other industries.
4. *Bacteria as the foes of man:* injurious effects of bacteria; methods of food preservation; proper methods of sweeping and dusting, with experiments; treatment of cuts; tuber-

culosis, its cause, prevention, and cure; pneumonia, its cause and prevention; diphtheria, its cause, treatment, and prevention; typhoid fever, its cause and prevention; water and milk supplies; (optional) smallpox and vaccination; (optional) hydrophobia and the Pasteur treatment; cause and prevention of other diseases; safeguards of the body against disease.

C. Foods and their Uses.

1. *Food substances found in the human body:* presence of proteins, fats, carbohydrates, mineral matters, and water in various parts of the human body.
2. *Necessity of foods:* (*a*) for growth, (*b*) for repair, (*c*) for the production of energy.
3. *Definition of a food.*
4. *Composition of foods:* food substances in milk; difference in the composition of animal and vegetable foods.
5. *Uses of each of the food substances:* comparison of the uses of the nutrients.
6. *Cooking of foods:* importance of proper cooking; reasons for cooking animal foods; principles involved in, (*a*) frying, (*b*) making soups, (*c*) stewing, (*d*) boiling meats, (*e*) roasting and broiling; reasons for cooking vegetables; boiling vegetables; bread making.
7. *Food economy:* importance of food economy; comparative cost of foods; economy in the purchase of foods; economy in the use of foods.
8. *Daily diet:* amount of each nutrient required; necessity for a mixed diet; avoidance of indigestible foods; sugar as a part of the diet.

D. Stimulants and Narcotics.

1. *Definition* and examples of each.
2. *Tea and coffee:* preparation of each; effect of each on body; use and abuse of each.
3. *Chocolate, cocoa, and other beverages:* composition; effects on body.
4. *Alcoholic beverages:* composition; alcohol as a stimulant and

narcotic; effects of small and large quantities of alcohol; Professor Hodge's experiment on dogs, as to the effects of moderate amount of alcohol in relation to, (*a*) activity, (*b*) skill and endurance, (*c*) nervousness, (*d*) offspring of the dogs, (*e*) resistance to disease; effect of alcohol on human beings in relation to, (*a*) mental activity, (*b*) muscular activity, (*c*) manual dexterity, (*d*) resistance to disease; alcohol and life insurance; business arguments for total abstinence; cost of intemperance.

5. *Tobacco:* effects, (*a*) on growth, (*b*) on mental development; tobacco and athletics.
6. *Drugs and patent medicines:* opium (morphine, laudanum, paregoric); acetanilid; dangers in the use of patent medicines; pure food and drug law.

E. Digestion and Absorption.

1. *General survey of the digestive system:* necessity for digestion; parts of the alimentary canal; digestive glands.
2. *Mouth cavity:* walls of the mouth cavity; structure and functions of the tongue.
3. *Teeth:* arrangement, kinds, number of each kind, functions; milk teeth; structure and care of teeth.
4. *Saliva and its functions:* experimental proof of the digestion of starch by saliva; position and action of salivary glands; uses of saliva.
5. (Optional.) *Throat cavity and gullet:* structure; functions.
6. *Stomach:* position, size, shape; lining of stomach and gastric glands; muscles of stomach; digestion in the stomach.
7. *Small intestine:* position, form, size; (optional) peritoneum; digestion in the small intestine.
8. (Optional.) *Large intestine:* position, form, size; vermiform appendix.
9. *Absorption from the alimentary canal:* necessity for absorption; absorption in mouth, throat, gullet, and stomach; absorption in the small and large intestine.
10. (Optional.) *Liver:* position, form, size; functions of the liver; functions of the bile.

11. *Hygiene of digestion:* hygienic habits of eating; prevention of disease; the use of water as a drink; effect of alcoholic drinks on the organs of digestion.

F. Circulation of the Nutrients.

1. *Blood:* structure of corpuscles; composition of plasma; hygiene of plasma.
2. *Circulation:* definition; necessity for; organs of circulation, definition of each.
3. *Heart:* position, size, shape; chambers, position and structure of each; valves; action of heart.
4. *Blood vessels:* position and structure of arteries; variations in pulse rate; valves in arteries; position, importance, and structure of capillaries: position and structure of veins.
5. *Course of the blood through the body:* changes in the composition of the blood.
6. *Hygiene of the circulation:* effect of exercise on the heart and blood vessels; stopping of blood flow in wounds.

G. Respiration and the Production of Energy in Man.

1. *Necessity for respiration:* proofs of oxidation in the human body; examples of energy in the human body; transformations of energy; respiration in plants, in animals, and in man.
2. *Adaptations for securing oxygen and for excreting carbon dioxid:* course taken by the air; nose cavity; throat and larynx; lining of the air passages; the lungs, their structure and blood supply; function of red corpuscles; change in color of blood after mixing with oxygen; hygiene of red corpuscles.
3. *The process of breathing:* structure of the chest cavity; (optional) pleura; enlargement of chest cavity; how air is taken into the lungs; breathing capacity of lungs; expiration.
4. *Hygiene of respiratory organs:* hygienic habits of breathing; effect of exercise on respiration; effect of tight clothing upon respiration; diseases of respiratory organs; suffocation; necessity of ventilation; methods of ventilation.

H. (Optional.) ADDITIONAL TOPICS IN HUMAN BIOLOGY.

1. *The skin:* characteristics; uses; layers; glands; importance of bathing; kinds of baths; care of the hair; care of the nails; treatment of burns; clothing; effect of alcohol on body temperature.
2. *The skeleton:* necessity for the skeleton; skeleton of the neck and trunk; skeleton of the arms and legs; skeleton of the head; joints; food and the skeleton; effect of pressure on the bones; fractures; dislocations; sprains.
3. *The muscles:* importance of muscle tissue; kinds of muscle; conditions necessary for healthy muscles (food, fresh air, exercise, rest); relation of muscles to posture.
4. *The nervous system:* the body as a collection of organs; coöperation of the organs; functions of the nervous system; parts of the nervous system; cellular structure of the nervous system; nerve impulses; reflex, conscious, and habitual activities; importance of habit; conditions necessary for a healthy nervous system (food, fresh air, varied activity, rest); effect of alcohol on the nervous system.
5. *The eyes:* protection for the eyes; structure of the eye; the eye as a camera; sensations of sight; defective eyes; hygiene of the eyes.
6. *The ears:* the external ear; the middle ear; sensations of sound.

I. (Optional.) THE LIVES AND WORKS OF GREAT BIOLOGISTS.

APPENDIX IV

LIST OF SUGGESTED BOOKS OF REFERENCE IN BIOLOGY

General Biology

1. Cyclopedia of American Agriculture. Edited by L. H. Bailey. 4 vols.—The Macmillan Co., N. Y. City. $20 net. Vol. I, Farms; Vol. II, Crops; Vol. III, Animals; Vol. IV, The Farm and the Community. We do not hesitate to say that Vols. II and III of this series are the most valuable books of reference known to us for teachers or students in plant and animal biology. Experts on the many subjects treated have epitomized in a readable form a vast amount of information which could only be found by patient search through many volumes. If schools cannot purchase these books, teachers might well urge that they be put on the shelves of the public library, for all four volumes will be found of great value as books of general reference, especially in rural communities.
2. Nature Study and Life, by Dr. C. F. Hodge.—Ginn and Co. $1.20. Contains many suggestions for the teaching of both plant and animal biology.
3. General Biology, by Sedgwick and Wilson.—Henry Holt and Co. $1.75. While mainly devoted to a consideration of the earthworm and the fern (both optional topics), this book will give teachers a clear idea of the biology of a plant and of an animal, and of the composition and characteristics of protoplasm. It also contains an admirable account of yeast, bacteria, Amœba, and Paramecium.
4. Teaching of Biology, by Lloyd and Bigelow.—Longmans, Green and Co. $1.50. Deals largely with methods of teaching nature study, botany, zoölogy, and human physiology.

Plant Biology

5. Practical Botany, by Bergen and Caldwell.—Ginn and Co. $1.30.
6. College Botany, by G. F. Atkinson.—Henry Holt and Co. $1.50.
7. Readers in Botany, by Jane C. Newell.—Ginn and Co. 2 vols. $.60 each.
8. How to know the Wild Flowers, by Mrs. William Starr Dana. —The Macmillan Co. $1.50.
9. How to know the Fruits, by Maude G. Peterson.—The Macmillan Co. $1.50.
10. Tree Book, by Julia E. Rogers.—Doubleday, Page and Co. $4.
11. Primer of Forestry. Vols. I and II. Gifford Pinchot.—U. S. Dept. of Agriculture.
12. New Creations in Plant Life, by W. S. Harwood.—The Macmillan Co. $1.75.
13. Bacteria, Yeast, and Moulds in the Home, by H. W. Conn.—Ginn and Co. $1.
14. Farmers' Bulletins, which can be obtained free by applying to the U. S. Dept. of Agriculture, Washington, D.C. The various Bulletins contain many important facts relating to both animals and plants.

Animal Biology

15. Animal Life, by Jordan and Kellogg.—Appleton. $1.20.
16. General Zoölogy, by Linville and Kelly.—Ginn and Co. $1.50.
17. American Natural History (vertebrates only), by W. T. Hornaday. $3.50.
18. Our Vanishing Wild Life, by W. T. Hornaday.—Chas. Scribner's Sons. $1.50.
19. Insect Book, by L. O. Howard.—Doubleday, Page and Co. $3.
20. Manual of Insects, by Comstock.—Comstock Publishing Co., Ithaca, N.Y. $3.75.
21. Insect Pests of Farm, Garden, and Orchard, by E. D. Sanderson.—John Wiley. $3.

22. Birds of Northeastern United States, by Frank Chapman.—Appleton. $3.
23. Bird Life (with colored plates), by Frank Chapman.—Appleton. $2.
24. Relation of Birds to Man, by Weed and Dearborn. Lippincott. $2.50.
25. Useful Birds and their Protection. Forbush. Mass. Dept. of Agriculture, Boston, Mass. $1.
26. Food and Game Fishes, by Jordan and Everman.—Doubleday, Page and Co. $4.
27. Farmers' Bulletins (see 14 above).
28. Story of the Fishes, by J. N. Baskett.—Appleton. $.65.

Human Biology

29. The Human Mechanism, by Hough and Sedgwick.—Ginn and Co. $2.50.
30. General Physiology, by W. H. Howell.— W. B. Saunders. $4.
31. Studies in Physiology, by James E. Peabody.—The Macmillan Co. $1.10.
32. Laboratory Exercises in Anatomy and Physiology, by James E. Peabody.—Henry Holt and Co. $.60.
33. Infection and Immunity, by George M. Sternberg.—Putnams. $1.75.
34. Pathogenic Microörganisms, by W. H. Park.—Lea Brothers and Co. $3.75.
35. Walter Reed and Yellow Fever, by H. A. Kelly.—McClure, Phillips and Co. $1.50.
36. The Malaria Mosquito, by B. E. Dahlgren.—American Museum of Natural History. $.15.
37. Fresh Air and How to Use It. Dr. Thomas Spees Carrington.—National Association for the Study and Prevention of Tuberculosis, 103 E. 22d St., New York. $1.
38. Physiological Aspects of the Liquor Problem (2 vols.). Dr. John S. Billings *et al.* Houghton & Mifflin. $4.50.

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Printed in the United States of America.